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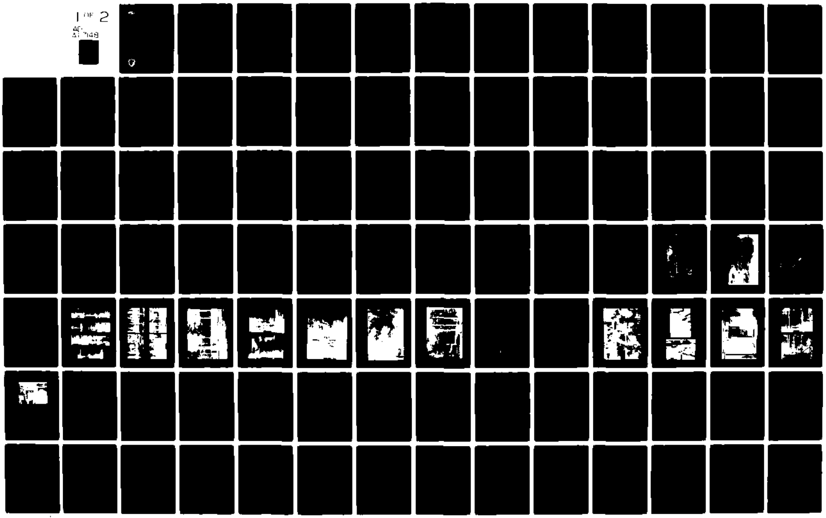

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A SURVEY OF MICROMETEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

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A field investigation of micrometeorological parameters inside and above a forest canopy at Fort Polk, Louisiana, was conducted in conjunction with the Atmospheric Sciences Laboratory Dusty Infrared Test IIIA. The three orthogonal components of the wind, dry- and wet-bulb temperatures and total solar radiation were measured inside this forest canopy by means of an instrumented meteorological tower. In addition, turbulence inside the forest canopy was monitored by means of hot-wire

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20. ABSTRACT (cont)

anemometers. Tethersonde balloon sounding above the forest canopy was further performed.

The meteorological data was reduced by means of three different statistical methods. Single sample period values, one-minute sample averages and sequential sample values were computed. The latter two methods led to the construction of time series which can readily be used to perform advanced statistical analyses. Totals of 27 h 29 min of meteorological tower data and 2 h 50 min of balloon data were reduced. The results are presented in tabular form in 1422 tables and partially displayed in 1795 figures under separate cover in view of their large volume. Selected samples of the results are, however, presented herein. The results supply a data base for analyses of airflow in a forest canopy. Suggestions for future work of significance for mission-oriented cases and for modeling of airflow in a forest canopy are outlined.

ACKNOWLEDGMENT

This field investigation was conducted for the U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range. Financial support for this field study provided by the Battelle Columbus Laboratories, Durham Operations, Scientific Services Program (Delivery Order No. 1535) is gratefully acknowledged.

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1. INTRODUCTION

A field investigation of the micrometeorological parameters within and above a forest canopy was conducted at Fort Polk, Louisiana, from 14 to 25 April 1980 in conjunction with the Atmospheric Sciences Laboratory Dusty Infrared Test IIIA (DIRT IIIA). The surveys during the DIRT IIIA blast tests were carried out on 16, 17, 18, 19, 21 and 23 April 1980. In addition, measurement of the background meteorological conditions during selected quiet periods-i.e., the prevailing meteorological conditions when no blast took place-was performed on 22, 23 and 24 April 1980 including the night of 22 to 23 April 1980.

The characteristics of the forest canopy and of the measurement site are outlined. Pine trees averaging 21.3 to 22.5 m (70 to 74 ft) in height with an average density of 1 tree/4.22 m^2 (960 trees/acre) surround the measurement site in all directions. Descriptions of the experimental setup, the instrumentation, the data acquisition systems, the calibration of the data logger and the calibration of the instruments are given herein.

Measurement of the wind, temperature and total solar radiation was accomplished using a meteorological tower 22.9 m (75 ft) high instrumented at five levels. The three orthogonal components of the wind, dry- and wet-bulb temperatures were measured at each level by identical UVW anemometers and two-thermocouple sensors, respectively. Total solar radiation was monitored at ground level and at tower top by means of two pyranometers. Surveys of the wind in the horizontal plane and of the dry- and wet-bulb temperatures above the forest canopy within heights above the ground ranging from 60 to 196 m (196.9 to 643 ft) were performed using a tethersonde balloon. In addition, turbulence inside the forest canopy was measured by means of two hot-wire anemometers mounted on a mast at 2.13 and 3.96 m (7 and 13 ft) above the ground.

Meteorological data was continuously recorded during both the blast tests and the quiet periods. Totals of 38 h of meteorological tower data, 1 h 45 min of balloon data and 23 h 30 min of hot-wire anemometer data were amassed during 27 blast tests. The corresponding amounts of data collected during the quiet periods are 20 h, 1 h 5 min and 19 h, respectively. This large volume of data far exceeded the initial planning but it was amassed because of the prevailing experimental conditions and the nearly flawless operation of the data acquisition systems. The reduction of this large amount of data was not feasible within the constraints of this program. As a result, 20 h 59 min of meteorological tower data amassed during 27 blast tests and 1 h 45 min of balloon data collected during 9 blasts were reduced. The 20 h 59 min of meteorological tower data were divided into pre- and post-blast sample periods for each one of the 27 blasts in order to determine the corresponding meteorological parameters. Similarly, the background meteorological data that was reduced amounted to 6 h 30 min of meteorological tower data and 1 h 5 min of balloon data. Reduction of the balance of the meteorological tower data (viz., 17 h of data during the blasts and 13 h 30 min of background meteorological data) and 42 h 30 min of hot-wire anemometer data is planned. However, achievement of this data reduction is contingent upon securing the needed time and manpower support.

The objective of the data reduction was to express the variation in time of the measured meteorological variables, which essentially are random variables, in terms of suitable statistical parameters. To this end, the mean value and standard deviation of the meteorological variables were computed for sample periods of selected time length. These two statistical parameters are of prime interest since they constitute the basic parameters needed for conducting any advanced analysis and interpretation of the meteorological data. They were estimated by using three different methods: (1) single sample period values; (2) one-minute sample averages; and, (3) sequential sample values. The single sample period analysis supplies a single characteristic value for an entire sample period. One-minute sample averages were introduced in order to construct time series over a given sample period. Such time series can be used for future probability, correlation and spectral analyses. Sequential sample mean values were advanced in order to generate time series whose members are weighted toward the time history of the random variable. Such a time series can be employed for future analysis concerning the degree of statistical stationarity of each variable and for identifying the occurrence of extreme values of significance within a given time history. These three methods were applied in reducing the wind, temperature and total solar radiation data.

Several special-purpose computer programs devoted to data preparation, which include data editing, conversion and preprocessing, were developed. General-purpose computer programs for data reduction according to the three different methods were constructed. Plotting routines for computer graphics were also developed.

The results reported herein consist of: (1) the three orthogonal components of the mean wind; (2) the mean wind in the horizontal plane; (3) the total mean wind; (4) the three orthogonal components of turbulence; (5) the turbulent wind in the horizontal plane; (6) the dry- and wet-bulb temperatures; (7) the potential temperature; (8) the relative humidity; (9) the dew-point temperature; and, (10) the total solar radiation. As far as the tethersonde balloon data is concerned, values over a 30 s time period of: (1) pressure; (2) dry-bulb temperature; (3) relative humidity; (4) mixing ratio; (5) wind in the horizontal plane; and, (6) potential temperature are reported.

The results are summarized in 1422 tables and 1795 figures presented in Appendices II through IX which are available under separate cover in view of their large volume. However, a typical sample of the results for a single post-blast sample period, a tethersonde balloon sounding during the blast tests and a single background meteorological data sample period are included here in Supplements I, II and III, respectively. The results are displayed in these three supplements in graphical form.

Inspection of the results clearly indicates that the undertaking of an analysis of the reduced data is of major significance. This available data base can efficiently be utilized to perform advanced probability, correlation and spectral analyses. Such analyses possess the potential to supply invaluable insight into the characteristics of airflow inside a forest canopy and to provide valuable information for modeling of this airflow for a variety of mission-oriented situations. These analyses are beyond the scope of the present program. However, all the necessary efforts to initiate such a study are being pursued in view of its considerable significance.

2. SITE DESCRIPTION

2.1 Forest canopy and blast area

The site of this field investigation was located in the Kisatchie National Forest on the Fort Polk Military Reservation, situated about 24.1 km (15 mi) ESE (112.5°) of Leesville, Louisiana. Climatological data of Leesville [1] is provided in Table 1 below. The test area is indicated on a regional topographic map (U.S.F.S. map) of the Fork Polk area given in Fig. 1.

The topography of the forest within a 12.9 km (8 mi) radius from the test area is characterized by gently rolling terrain with an average height contour gradient of 45 m/km (238 ft/mi). Pine and oak are the predominant trees of this forest. An aerial photograph of the forest canopy in which all the relevant sites-viz., tower site, tethersonde site, blast area, north instrumentation and south instrumentation sites-along with the geographic orientation is provided in Fig. 2. The blast area was situated within a large clearing measuring about 900x500 m (2952x1640 ft) covered in all directions by fern and patches of young trees.

2.2 Meteorological tower site and tethersonde balloon site

The meteorological tower site was located at 150° with respect to and at a distance of 400 m (1310 ft) from the blast area within a dense and homogeneous pine grove as indicated in the local topographic map given in Fig. 3. The tower site clearing, whose plan view is depicted in Fig. 4, is irregular in shape and covered an area of about 18.6 m^2 (200 ft^2). A 46 m (150 ft) forest fetch separates the meteorological tower clearing from the eastern perimeter of the blast area clearing. Pine trees averaging 21.3 to 22.5 m (70 to 74 ft) in height with an average tree density of 1 tree/4.22 m^2 (960 trees/acre) surround the tower site clearing in all directions. North of the tower, the average height contour gradient deviates from near horizontal to a slope of -0.091. In this direction, oak trees of an average height of 13.7 m (45 ft) tall prevail within 200 m (656 ft) from the tower. A description of the forest canopy and trees in the vicinity of the tower (within more than 100 m (300 ft)) is given in Table 2 below (data supplied by U.S.F.S., Vernon Range District Station, Louisiana).

A 360° panoramic view of the surroundings of the site as observed from the tower is provided in Fig. 5. The directions annotated in this figure and in Figs. 6, 7, 8, 9 and 17 indicate the direction at which a viewer is looking. Four overall views of the tower site seen at different angles are shown in Fig. 6. A close-up view of the tower site showing the tower, the digital data acquisition system located in a trailer (digital recording trailer) and the mobile data acquisition van is given in Fig. 7.

The tethersonde balloon site was situated about 350 m (1148 ft) from the blast area on the northeast edge of its clearing. With respect to the tower site, the tethersonde site is located just outside of the pine grove about 50 m (164 ft) from the tower in the direction of the

TABLE 1. CLIMATOLOGICAL DATA FOR LEESVILLE, LOUISIANA [1]

Leesville, LA — 1951-1973 — 31°09' N — 93°16' W — 200 ft

Temperature (°F)

	Means			Extremes						Mean Number of Days			
										Max		Min	
Month	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Day	Record Lowest	Year	Day	90° and above	32° and below	32° and below	0° and below
JAN	60.8	37.9	49.4	81+	71	31	6	62	12	0	1	12	0
FEB	64.3	39.9	52.1	86	57	10	7	51	2	0	0	8	0
MAR	71.1	45.8	58.5	89+	67	27	19	68	1	0	0	4	0
APR	78.7	54.8	66.8	92	63	10	29	62	2	0	0	0	0
MAY	84.7	60.7	72.7	95+	58	27	39	60	13	5	0	0	0
JUN	90.5	66.8	78.6	100+	63	13	48+	56	3	20	0	0	0
JUL	92.8	69.8	81.3	104	54	25	53	67	15	26	0	0	0
AUG	92.7	68.7	80.7	106	62	12	49	56	24	25	0	0	0
SEPT	88.6	64.1	76.4	101+	63	5	35	67	29	16	0	0	0
OCT	80.7	52.5	66.6	96	54	6	24	52	29	3	0	1	0
NOV	69.9	44.3	57.1	88	72	1	19	59	29	0	0	5	0
DEC	62.8	39.6	51.2	80+	71	10	12+	63	24	0	0	10	0
YEAR	78.1	53.7	66.0	105	62	AUG 12	6	62	JAN 12	95	1	40	0

Precipitation Totals (inches)

							Snow Sleet						Mean Number of Days		
Month	Mean	Greatest Monthly	Year	Greatest Daily	Year	Day	Mean	Maximum Monthly	Year	Greatest Depth	Year	Day	10 or more	50 or more	1.00 or more
JAN	4.21	10.82	51	4.20	51	03	.2	3.0	73	3.0	73	12	7	3	1
FEB	4.78	14.65	66	11.00	66	10	.5	10.0	60	10.0	60	13	7	3	1
MAR	4.20	8.41	73	4.15	64	02	.0						6	3	1
APR	5.19	13.75	53	8.45	53	29	.0						6	3	2
MAY	5.17	20.82	53	8.12	53	18	.0						6	3	2
JUN	4.16	9.78	73	4.68	60	26	.0						5	3	1
JUL	5.27	11.58	55	4.30	55	14	.0						7	4	2
AUG	3.70	10.16	55	4.97	55	03	.0						6	2	1
SEPT	3.65	11.86	58	4.84	61	13	.0						6	2	1
OCT	3.01	11.07	70	4.83	70	12	.0						4	2	1
NOV	4.15	13.66	57	3.42	68	28	.0						5	3	1
DEC	5.97	11.06	67	3.73	69	07	.0						7	4	2
YEAR	53.46	20.82	MAY 53	11.00	FEB 66	10	.7	10.0	FEB 60	10.0	FEB 60	13	72	36	16

+also on earlier dates

TABLE 2. FOREST CANOPY TREE DATA.

Tree Genus	Species	Average Height (m)	Average Height (ft)	Average Density (Average Basel Area-no. of trees/acre)	Average Diameter at Breast Height (DBH; at 4½' above ground) (cm)	Average Diameter at Breast Height (DBH; at 4½' above ground) (in)	Average Crown Width (m)	Average Crown Width (ft)	Average Age (years)
Pine (Pinus)	Shortleaf pine Longleaf pine Loblolly pine	21.9	72	960	32.46	12.78	6.1	20.0	32
Oak (Quercus)	Southern red oak White oak Post oak	13.7	45	700	38.10	15.0	5.6	18.5	40

blast area (in the northwest direction). Two views of the tethersonde site are given in Fig. 8. Proximity of the tethersonde site in relation to the forest canopy, edge of the blast area clearing (immediate foreground), meteorological tower and mobile data acquisition van is illustrated in the still photograph provided in Fig. 9.

3. EXPERIMENTAL SETUP AND INSTRUMENTATION

3.1 Meteorological tower

A telescopic tower 22.9 m (75 ft) high of equilateral triangular design with diagonal cross members was erected and secured by guy wires. A photograph of this tower is given in Fig. 10. Wind and temperature sensors (a UVW anemometer and a shielded dual-thermocouple), a photograph of which is provided in Fig. 11, were attached to the two ends of supporting arms which were, in turn, mounted on the tower. With respect to the tower, the wind sensors were located on its north side while the temperature sensors were on the opposite side.

In order to obtain the wind shear and temperature (dry- and wet-bulb temperature) vertical distributions within the forest canopy, the sensors were located at the following five heights: (1) at about 1/3 the trunk height; (2) at the base of the crown; (3) at about 1/3 and 2/3 of the height of the crown measured from its base; (4) at crown top. The heights above ground of the anemometers were: 1.9, 6.4, 11.7, 16.8, 21.3 m (6.3, 21, 38.3, 55, 70 ft) while the temperature sensors were mounted 0.5 m (1.5 ft) below the anemometers. A sketch of the meteorological tower including the heights of the measuring instruments which is in proportion to the height of an average tree (21.9 m (72 ft)) is shown in Fig. 12.

Measurement of the three orthogonal components of the wind at each level was accomplished by using Gill UVW anemometers (R. M. Young Co., Model 27004 [2]). Each anemometer employs an orthogonal array of three identical 22.9 cm (9 in) diameter four-blade polystyrene propellers of helicoid design. Each propeller is designed for an optimum dynamic response up to a maximum wind speed of 22.35 m/s (50 mph) [2]. The response at low-speed winds is enhanced as a result of installing a 76.2 mm (3 in) extension in place of the propeller nut. This provides a more symmetric physical configuration on both sides of the propeller thereby improving the low-speed response in a stall situation (i.e., for a wind normal to propeller axis, 90° wind). The calibration of each UVW anemometer was found to be in reasonable agreement with those given by the manufacturer. An analog output voltage proportional to the wind speed is supplied by a built-in miniature DC generator which is driven by the propeller motion. The output voltage is either positive or negative depending on which way the propeller turns, i.e., counterclockwise or clockwise. Each UVW anemometer was installed so that north, east and downward winds produced a positive output voltage. This sign convention and the system of coordinates employed in this experiment are depicted in Fig. 13.

Dry- and wet-bulb temperatures were monitored by a sensor consisting of two copper-constantan (T-type) thermocouples. The thermocouple used to measure the wet-bulb temperature was installed within a ceramic housing inside of which a moist environment was sustained. Water vapor ventilated to the housing was provided by means of a water reservoir in conjunction with a 3160 rpm squirrel cage fan (Dayton Electric Mfg., Model 2C782) attached to the end of the sensor. Wet-bulb reservoirs were refilled with water every couple of days except for the one at the top level which could not be reached after the tower was erected. Both thermocouples were protected from solar radiation by a blanket of polystyrene insulation encased in an aluminum shield which was painted white. A photograph of the thermocouple assembly is given in Fig. 14.

Total solar radiation (i.e., direct and diffuse) above the forest canopy (at the tower top) and at ground level was monitored by means of two pyranometers (Eppley Labs, Inc., Models PSP and 15, respectively). One pyranometer was installed at the tower top-i.e., at 22.9 m (75 ft) above the ground-as shown in Fig. 12. The ground level pyranometer was placed 11.6 m (38 ft) north of the tower on the edge of the site clearing to ensure that its measurements would be representative of solar radiation received within the forest canopy. Views of the pyranometers-viz., tower top and ground level-are provided in Fig. 15. The location of the ground pyranometer with respect to the tower and site clearing is indicated in Fig. 4 and illustrated in the panoramic view of the site given in Fig. 5.

3.2 Tethersonde balloon

An instrumented tethersonde balloon was used to conduct vertical sounding of the atmospheric boundary layer up to a height of about nine times the canopy average height, i.e., up to about 196 m (643 ft) above ground. Daily vertical soundings were generally conducted in the morning (8-9 a.m.), afternoon (12-1 p.m.) and early evening (4-5 p.m.). The tethersonde system (Atmospheric Instrumentation Research Co., Type TS-1A-1) consists of a 3.25 m^3 (115 ft^3) helium filled blimp-shaped balloon, an airborne telemetry package, a ground receiver and a battery powered winch. Instruments in the airborne package measure:

(1) horizontal wind speed by means of a 3-cup anemometer;

(2) wind-direction in the horizontal plane by means of a magnetic compass in conjunction with the behavior of the balloon acting as a wind vane;

(3) pressure change with respect to the barometric surface pressure by means of a temperature-compensated aneroid transducer;

(4) dry-bulb temperature by means of a thermistor;

(5) wet-bulb temperature with the aid of a thermistor enshrouded by a water-saturated wick.

A record of all five instrument readings was transmitted to a ground receiver every 30 s. On-line reduction and recording of the data on a paper tape was accomplished by means of a microprocessor and a modified calculator equipped with a printer (Hewlett-Packard Co., Model HP-97). These are integral components in the ground package of the balloon system.

4. DATA ACQUISITION

4.1 Digital Data Acquisition System

A Digital Data Acquisition System (DDAS) was used for on-line recording of the 15 anemometer, 10 temperature and 2 pyranometer sensors output signals, i.e., a total of 27 signals. It was located in a digital recording trailer as indicated in Fig. 7. This DDAS, a photograph of which is provided in Fig. 16, consisted of: (1) a 60-channel data logger (Fluke Mfg. Co., Model 2240A) which included an analog-to-digital converter, a thermocouple block and a paper tape printer; and, (2) a 9-track digital magnetic tape recorder (Kennedy Co., Model 1600). An in-line patch board, which is also shown in Fig. 16, enabled desired Gill anemometer signals to be routed to the mobile data acquisition van for analog recording.

Since only 27 channels were required for this experiment, the remaining 33 data logger channels were shorted. Calibration of these 27 channels was checked before and after the data collection as described in Appendix I.1. Anemometer and pyranometer channels were calibrated over a nominal range from 0 to 4 V DC against a known input voltage supplied by a highly accurate laboratory standard DC voltage generator. The data logger thermocouple blocks, which house the thermocouple channels, instantly converted incoming thermocouple voltages to readings in degrees centigrade which were then recorded on magnetic tape. Calibration of the thermocouple channels was accomplished by means of a thermocouple under known conditions. The calibration for each channel was expressed by a linear relation between the input and output signals. All the calibration equations are given in Appendix I.1. In addition, the conversion relations for the anomometers and the pyranometers-i.e., conversion from electrical to physical units-are outlined in this appendix. These conversion relations were obtained by calibration of each instrument.

A sampling rate of 12 channels per second was used for the analog-to-digital converter. As a result, the time period per channel (or per data point) Δt was 83.3 ms. The cutoff frequency (or the Nyquist frequency) which is given by [3]

$$f_c = \frac{1}{2\Delta t} , \tag{4.1}$$

was thus 6 Hz. A scan of all 27 signals, which is called a record herein, was obtained within a time interval of 2-1/4 s (27x0.0833 s). Any two records were thus separated by a 2-3/4 s time interval of no data since the remaining 33 shorted channels were also scanned (33x0.0833 s). In other words, 27 data points were recorded every 5 s or 324 data points per minute.

Checking of the data recording was conducted by printing out one record of data on the built-in paper tape at intervals of: (1) 2 minutes on 17 April 1980; (2) 1 minute on 18 April 1980; and, (3) 5 minutes on 19, 21, 22 and 23 April 1980. Background meteorological data collected on 24 April 1980, when no blast occurred, was recorded continuously with the paper tape printer off. Limitations of the printer hardware resulted in a slower sampling rate of the data. When the data logger was in the printing mode, the sampling rate and subsequent recording rate decreased by a factor of five to a time period Δt of 417 ms per channel (2.4 channels/s). Bearing in mind the fact that it took five times longer to scan one record of data, the corresponding Nyquist frequency was 1.2 Hz. Then each data record (27 channels) was 11-1/4 s long and separated by 13-3/4 s time interval of no data (33 shorted channels). Thus, in the printing mode 27 data points were recorded every 25 s. The printer was usually activated for a single data record per minute-i.e., a scan of 27 channels per minute-at the selected time interval as previously indicated. Then the total number of data points per minute was 216, viz., 27 data points during the first 25 s when the printer was on and 189 data points during the remaining 35 s with the printer off (27 data points/5 s x 35 s + 27 data points/25 s x 25 s = 216 data points/min).

4.2 Analog data recording

Turbulence measurements were conducted using two hot-wire anemometers mounted on a mast at 2.13 and 3.96 m (7 and 13 ft) above ground level as shown in the two views given in Fig. 17. The hot-wire mast was situated NNE (22.5°) from the tower at a distance of 6.3 m (20.6 ft) as indicated in Fig. 4. Details and results of the hot-wire data are presented in a separate forthcoming report. However, the mobile hot-wire recording facility is briefly described herein.

The Mobile Data Acquisition Van (MDAV), shown in Fig. 7, was located near the DDAS and was instrumented with an Analog Data Acquisition System (ADAS) for hot-wire data recording. The ADAS, a picture of which is provided in Figure 18, consists of the following equipment:

(1) Four hot-wire anemometers (Colorado State University, Fluid Dynamics and Diffusion Laboratory);

(2) A 14-channel analog FM tape recorder (Ampex Corp., Portable Instrumentation Magnetic Tape Recorder/Reproducer, Model FR-1300) for recording of hot-wire signals and selected Gill UVW anemometer signals;

(3) A wave analyzer (General Radio Co., Recording Sound and Vibration Analyzer, Type 1911) for on-line frequency spectral analyses of the hot-wire signals;

(4) A digital DC voltmeter (Hewlett-Packard Co., Model 3440A) for monitoring DC output voltages;

(5) Two dual-beam oscilloscopes (Tektronix Inc., Model 502A) for calibration, monitoring and checking of the hot-wire signals during recording;

(6) Two true root-mean-square meters (Disa Inc., Type 55D35) for measuring rms values;

(7) A variable electronic filter (Spencer-Kennedy Labs Inc., Model 308A) for high-pass and low-pass filtering of the hot-wire signals;

(8) Two function generators (Hewlett-Packard Co., Oscillator, Model 209A) for recording of identification headers on tape and check-out of the hot-wire units;

(9) One X-Y recorder/plotter (Hewlett-Packard Co., Model 7035A) for hard copy reproduction capabilities;

(10) Five variable gain DC amplifiers (Dana Electronics, Inc., Model 3500) for amplification of Gill UVW anemometer signals when analog recording.

5. DATA COLLECTION RECORD

5.1 Data collection during blast tests

Measurement of the meteorological parameters-viz., the three wind components, dry- and wet-bulb temperatures and total solar radiation-within the forest canopy before and after each blast was the major objective of this investigation. The blasts took place on 16, 17, 18, 19, 21, 22 and 23 April 1980 at given times with a time interval between two consecutive blasts ranging from 36 to 89 minutes. In order to obtain sufficiently long sample periods before and after each blast, the meteorological data was continuously recorded independently of the blast test sequence. The data logger malfunctioned on April 16, 1980, and, consequently, no digital data was recorded that day.

Herein, the sample period before and after each blast is called pre- and post-blast sample period, respectively. In reducing the data, the longest sample period employed amounted to a time length of 30 minutes. In many instances, however, shorter pre- and/or post-blast sample periods were used because of the given time interval between two consecutive blasts. As a result, the sample period ranged from 17 to 30 minutes except a single pre-blast sample period whose time length was 4 minutes. This short sample period happened on 18 April 1980 at the very beginning of the blast test sequence because of a fuse failure in the data logger. A summary of the DIRT IIIA blast test sequence on 17, 18, 19, 21, 22 and 23 April 1980 is given in Table 3 below. The blast time (Central Standard Time denoted by CST), the test code, the pre- and post-blast sample periods and their net time length in minutes are tabulated in this table. Since 27 blasts took place on these 6 days, 54 pre- and post-blast sample periods of a total time length of 20 h 59 min are tabulated in this table.

The three-part test code provides the following information: (1) the blast number denoted by one or two digits; (2) the DIRT IIIA blast type designated by a letter and a digit; and, (3) the pre- or post-blast sample period indicated by BB (before blast) or AB (after blast). For example, 20-E5-BB designates the pre-blast sample period for the twentieth blast of DIRT IIIA type E5.

The number of data points (or number of channels recorded) per sample period varied according to the operating mode of the data logger. Recall that the number of data points recorded every minute was either 324 or 216 depending upon whether the built-in printer was off or on as previously mentioned in Sect. 4.1. With the data logger in its usual operating mode-viz., printer off-the number of data points ranged from 5508 to 9720 per sample period of time length varying from 17 to 30 minutes. In the single case of a 4 minute sample period, the number of data points was 1296. Whenever, the paper tape printer was activated the number of data points per sample period decreased according to the number of times that the printer was in operation. For instance, when the printer was on every 5 minutes, the number of data points per a sample period 30 minutes long was 9072 (24 minutes with printer off x 324 data points/min = 7776 data points plus 6 minutes with printer on x 216 data points/min = 1296 data points).

TABLE 3. BLAST TEST SEQUENCE

Date	Blast Time (CST)	Test Code	Pre- and Post-Blast Sample Period (CST)	Minutes Per Sample Period
4/17/80	12:39	1-A4-BB	12:09 - 12:39	30
		1-A4-AB	12:39 - 13:05	26
4/18/80	09:08	2-D4-BB	09:03 - 09:07	4
		2-D4-AB	09:08 - 09:30	22
	09:53	3-A5-BB	09:30 - 09:53	23
		3-A5-AB	09:53 - 10:13	20
	10:34	4-A6-BB	10:13 - 10:34	21
		4-A6-AB	10:34 - 10:55	21
	11:16	5-A8-BB	10:55 - 11:16	21
		5-A8-AB	11:16 - 11:39	23
	12:03	6-C7-BB	11:39 - 12:03	24
		6-C7-AB	12:03 - 12:33	30
	13:32	7-D5-BB	13:02 - 13:32	30
		7-D5-AB	13:32 - 13:53	21
	14:13	8-D6-BB	13:53 - 14:13	20
		8-D6-AB	14:13 - 14:32	19
	14:51	9-C5-BB	14:32 - 14:51	19
		9-C5-AB	14:51 - 15:21	30
4/19/80	11:50	10-C4-BB	11:33 - 11:50	17
		10-C4-AB	11:50 - 12:08	18
	12:26	11-B4-BB	12:08 - 12:26	18
		11-B4-AB	12:26 - 12:56	30
	13:27	12-B6-BB	12:57 - 13:27	29
		12-B6-AB	13:27 - 13:51	24
	14:15	13-B7-BB	13:51 - 14:15	24
		13-B7-AB	14:15 - 14:38	23

TABLE 3. (CONTINUED)

Date	Blast Time (CST)	Test Code	Pre- and Post-Blast Sample Period (CST)	Minutes Per Sample Period
	15:01	14-D9-BB	14:38 - 15:01	23
		14-D9-AB	15:01 - 15:19	18
4/21/80	13:12	15-C6-BB	12:42 - 13:12	30
		15-C6-AB	13:12 - 13:34	22
	13:56	16-A7-BB	13:34 - 13:56	22
		16-A7-AB	13:56 - 14:26	30
	15:00	17-B8-BB	14:30 - 15:00	30
		17-B8-AB	15:00 - 15:18	18
	15:36	18-E7-BB	15:18 - 15:36	18
		18-E7-AB	15:36 - 15:55	19
	16:15	19-E8-BB	15:55 - 16:15	20
		19-E8-AB	16:15 - 16:37	22
	16:58	20-E5-BB	16:37 - 16:58	21
		20-E5-AB	16:58 - 17:15	17
4/22/80	12:12	21-B5-BB	11:42 - 12:12	30
		21-B5-AB	12:12 - 12:42	30
	14:03	22-D8-BB	13:33 - 14:03	30
		22-D8-AB	14:03 - 14:33	30
	15:24	23-E6-BB	14:54 - 15:24	30
		23-E6-AB	15:24 - 15:49	25
	16:14	24-A9-BB	15:49 - 16:14	25
		24-A9-AB	16:14 - 16:44	30
4/23/80	09:37	25-B9-BB	09:10 - 09:37	27
		25-B9-AB	09:37 - 09:56	19
	10:15	26-C8-BB	09:56 - 10:15	19
		26-C8-AB	10:15 - 10:33	18
	10:52	27-C9-BB	10:33 - 10:52	19
		27-C9-AB	10:52 - 11:22	30

5.2 Background data collection

Measurement of the meteorological variables during several quiet periods was further carried out in order to obtain information on the prevailing background meteorological conditions within the forest canopy. A quiet period is one when no blast took place. The prevailing meteorological conditions are called herein background meteorological data. Surveys of the background meteorological data were conducted from 6:00 p.m. on 22 April 1980 until 8:30 a.m. on 23 April 1980, and from 11:00 a.m. until 4:30 p.m. on 24 April 1980. A summary of the test sequence for the background meteorological data is given in Table 4 below for 13 representative sample periods.

TABLE 4. BACKGROUND METEOROLOGICAL DATA TEST SEQUENCE

Date	Test Code	Sample Period (CST)	Minutes Per Sample Period
4/22/80	BMD-22-1	18:00 - 18:30	30
	BMD-22-2	20:00 - 20:30	30
	BMD-22-3	22:00 - 22:30	30
4/23/80	BMD-23-1	01:00 - 01:30	30
	BMD-23-2	04:00 - 04:30	30
	BMD-23-3	06:00 - 06:30	30
	BMD-23-4	08:00 - 08:30	30
4/24/80	BMD-24-1	11:00 - 11:30	30
	BMD-24-2	12:00 - 12:30	30
	BMD-24-3	13:00 - 13:30	30
	BMD-24-4	14:00 - 14:30	30
	BMD-24-5	15:00 - 15:30	30
	BMD-24-6	16:00 - 16:30	30

In the table above, the test code, the sample period and its time length in minutes are tabulated. The three-part test code supplies the following information: (1) identification of the background meteorological data by BMD; (2) the date when the survey was performed; and, (3) the test number during that day. For instance, BMD-23-3 denotes the test no. 3 of the background meteorological data conducted on 23 April 1980. All the sample periods of the background meteorological data were 30 minutes long and, hence, the total time length of these 13 sample periods is 6 h 30 min. This data was collected with the data logger in its normal operating mode, viz., with the printer off. As a result, the number of data points per sample period was always 9720.

5.3 Tethersonde balloon data collection

Vertical sounding above the forest canopy was conducted by means of a tethersonde balloon as described in Sect. 3.2. This balloon sounding was carried out daily during the blast experiment on 18, 19, 21, 22 and

23 April 1980, and during the quiet period on 22, 23 and 24 April 1980. The number of vertical sounding ranged from one to three per day. An outline of the balloon test sequence during the blast and quiet periods are given below in Tables 5.1 and 5.2, respectively, in which the sample period and its time length in minutes along with the maximum altitude reached by the balloon are summarized. In order to identify the timing of the balloon survey with regard to the blast schedule (see Table 3), the time and test code of the closest blast before or after the balloon sounding are given in Table 5.1. The test code for the balloon surveys during the quiet period is similar to that used for the background meteorological data given in Table 4.

TABLE 5. TETHERSONDE BALLOON TEST SEQUENCE

Table 5.1 During Blast Tests

Date	Closest Blast Before/After Balloon Sounding		Balloon Sounding			
	Blast Time (CST)	Test Code	Sample Period (CST)	Minutes per Sample Period	Maximum Altitude (m)	(ft)
04/18/80	14:51	9-C5-AB	15:44 - 15:48	4	71	232.9
04/19/80	12:26	11-B4-AB	12:38 - 12:49	11	65	213.3
	15:01	14-D9-BB	14:41 - 14:48	7	89	292.0
04/21/80	13:12	15-C6-BB	09:23 - 09:36	13	165	541.3
	13:12	15-C6-AB	13:20 - 13:29	9	155	508.5
	16:15	19-E8-BB	16:01 - 16:11	10	159	521.7
04/22/80	14:03	22-D8-BB	13:48 - 13:53	5	136	446.2
	16:14	24-A9-AB	16:29 - 16:39	10	193	633.2
04/23/80	09:37	25-B9-BB	08:37 - 08:59	22	175	574.1
	10:52	27-C9-AB	11:23 - 11:37	14	179	587.3

Table 5.2 During Quiet Period

Date	Balloon Sounding				
	Test Code	Sample Period (CST)	Minutes per Sample Period	Maximum Altitude (m)	(ft)
04/22/80	BMD-22-1	18:44 - 18:57	13	157	515.1
04/23/80	BMD-23-1	05:58 - 06:12	14	196	643.0
04/24/80	BMD-24-1	10:07 - 10:27	20	170	557.7
	BMD-24-2	13:07 - 13:21	14	178	584.0
	BMD-24-3	16:00 - 16:04	4	60	196.9

The sample period given in these two tables represent either the ascent or descent time interval. Selection of either one as a sample period was based in each case on a preliminary evaluation of the recorded data. The sample period ranged from 4 to 22 minutes and the maximum altitude attained by the balloon varied from 60 to 196 m (196.7 to 643 ft). Recall that the average height of the forest canopy is 21.3 to 22.5 m (70 to 74 ft). Note that the balloon rate of ascent and/or descent was not the same in all cases because of changes in the prevailing wind and release rate of the tetherline. The balloon height was determined based on the change in the atmospheric pressure (in mb) with respect to the barometric surface pressure by means of a built-in altimeter. Thus, the total time lengths of the balloon sounding sample periods during the blast tests and during the quiet periods were 1 h 45 min and 1 h 5 min, respectively.

The five meteorological variables measured by the air-borne package over a time interval of 30 s were reduced on-line by the microprocessor included in the ground package as previously mentioned in Sect. 3.2. As a result of this on-line data reduction, a record of the following seven variables was supplied by the ground package every 30 s: (1) pressure in mb; (2) dry-bulb temperature in degrees centigrade; (3) relative humidity; (4) mixing ratio (or specific humidity); (5) wind speed in m/s; (6) wind direction (azimuth in the horizontal plane at each height); and, (7) potential temperature in degrees kelvin. Then the total number of data points per sample periods of 4 to 22 minutes ranged from 56 to 308 ((240 to 1320 s)/30 s record x 7 data points/record). The number of data points for each one of the seven variables per sample period varied thus from 8 to 44 (56 to 308 data points per sample period/7 variables).

6. DATA REDUCTION METHODS

Data on wind, temperature and total solar radiation was obtained in a discrete form in this investigation. All the discrete data points represent values which the random variables being measured are taking on within each sample period. As a result, the objective of the data reduction was to express the variation in time of the measured quantities in terms of suitable statistical parameters. The basic statistical parameters of interest are the mean value and the standard deviation. Estimators of these statistical parameters are unbiased, efficient and consistent [3] and, therefore, they supply adequate estimates.

Mean and standard deviation values were computed using three different methods. In presenting these methods, a discrete random variable $x(t)$ which is defined for points t from the sample time is considered herein for generality sake. This random variable may assume a finite number N of discrete independent observed values within a finite sample period (or time history) which constitutes the sample size. In practice, this random variable $x(t)$ represents the measured discrete values of wind, temperature or solar radiation in the corresponding physical units. The sample mean $\bar{x}$ and sample standard deviation σ_x for N independent data points (or observed values) are given by the relationships

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i \ , \tag{6.1}$$

and

$$\sigma_x = \left[\frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2 \right]^{\frac{1}{2}} , \tag{6.2}$$

where x_i designates the ith instantaneous observed value of the random variable $x(t)$. In computing the standard deviation, the summation was divided by the total number of data points N per sample instead of $N - 1$ in view of the relatively large number of data points available.

6.1 Single sample period values

The first method consists of representing the random variable $x(t)$ by means of a single mean value and a single standard deviation for an entire sample period, i.e., for the entire measured time history. These values are called herein the single sample period mean value (or arithmetic mean) and standard deviation. They were estimated by means of Eqs. (6.1) and (6.2) when the total number N of data points per sample-i.e., the entire sample size-was used.

The average minimum and maximum number of data points per single sample period for all the 27 variables monitored and for each variable with the data logger in normal operating mode (printer off) are given in Table 6 below:

TABLE 6. SAMPLE SIZE

Sample period time length (min)	17	30
Single sample size/27 variables	5508[1]	9720[2]
Single sample size/one variable	204	360
One-minute sample size/one variable	12	12

When the printer was activated, the corresponding one-minute sample size per one variable constitutes 8 data points, i.e., 1 data point for the 25 s when the printer was on and 7 data points for the remaining 35 s during which the data logger resumed its normal operation (viz., printer off). The total single sample size is consequently a function of the printing time interval and number of minutes in the sample period.

6.2 One-minute sample average

In order to describe the variation with time of the random variable $x(t)$ over a sample period of a given finite time length, it is necessary to construct a corresponding time series. To this end, one-minute sample average was introduced. Each one-minute sample average, denoted here by λ is viewed as an estimate of the instantaneous value of the random variable $x(t)$. Then one can represent the discrete instantaneous values of the random variable within any sample period of a time length of M minutes by a set of M one-minute sample average values, i.e., by a set of λ_j values, where $j = 1$ to M. This set constitutes a time series which can be used to conduct probability, correlation and spectral analysis of the data.

Each one-minute sample average λ was computed by applying Eq. (6.1). Thus,

$$\lambda = \frac{1}{N} \sum_{i=1}^{N} x_i , \tag{6.3}$$

in which x_i denotes the ith measured value of the random variable $x(t)$ and N is the total number of observed values per one minute, i.e., N is the sample size per one-minute time history. In computing the one-minute sample average for each one of the 27 variables measured in the experiment, the average number of data points was 12 or 8 depending upon whether the data logger printer was off or on.

The mean value $\bar{\lambda}$ and the standard deviation σ_λ of the time series contructed of the one-minute sample averages were estimated by means of Eqs. (6.1) and (6.2), i.e.,

[1]324 data points/min x 17 min; [2]324 data points x 30 min.

$$\bar{\lambda} = \frac{1}{M}\sum_{j=1}^{M} \lambda_j \ , \tag{6.4}$$

and

$$\sigma_\lambda = \left[\frac{1}{M}\sum_{j=1}^{M} (\lambda_j - \bar{\lambda})^2\right]^{\frac{1}{2}} \ , \tag{6.5}$$

where λ_j denotes the jth one-minute sample average and M stands for the total number of minutes per sample period.

6.3 Sequential sample values

An issue of prime concern in analyzing random data is to determine the time length of a sample period (or sample record) over which an invariant mean value is obtained, i.e., a stationary mean value. A random process is said to be weakly stationary when the mean value and the autocorrelation are invariant with increasing time length of the sample record. Generally, the mean value varies with increasing time till it eventually reaches a constant value if the process is statistically stationary. The time length over which such an invariant mean value is attained is viewed as a first approximation of the time scale for weakly statistical stationarity. A better approximation of this time scale is obtained when the autocorrelation also remains invariant with increasing time.

In order to gain insight into the variation of the mean value with increasing time length of a sample record, a sequential (or running) sample mean value $\mu(t)$ was advanced. Sequential sample mean values (or sequential averages) are essentially the mean values of a sample record of a continually increasing time length. As the time length of the sample record increases, an ensemble (or a set) of sequential sample mean values $\mu_k(t)$ is obtained, where the subscript k denotes each individual sample record (i.e., each kth sample record). One can assume that a random process is weakly statistical stationary in the mean sense (or to a first approximation) if the value of the sequential mean value remains invariant as the time length of the sample record approaches the total time length of the available single sample period, i.e., as $\mu_k(t) \cong \bar{x}$ with increasing time length.

In computing the sequential sample mean values, the time length of the sample record was incremented in equal steps of one-minute segment. Thus, for a sample period of a total time length of M minutes, M sequential sample mean values were obtained. Each sequential sample mean value μ_k was estimated by means of Eq. (6.1) in the form

$$\mu_k = \frac{1}{N_k} \sum_{i=1}^{N_k} x_i \ , \ k = 1 \text{ to } M \ , \qquad (6.6)$$

where x_i is the ith instantaneous measured value of the random variable $x(t)$, $k = 1$ to M indicates the number of one-minute segments comprised within the kth sample record, M is the total number of one-minute segments per a given sample period and N_k designates the total number of data points per a sample record of k minutes length. Thus, the kth sequential sample mean value μ_k is simply the mean value of the observed values of the random variable $x(t)$ over the first k minutes of the sample period. It is important to notice that the first sequential sample mean value μ_1 is equal to the first one-minute sample average (see Sect. 6.2) and the last μ_M is equal to the single sample mean value of the entire sample period, i.e., the single sample period mean value $\bar{x}$ (see Sect. 6.1).

One further can view the ensemble of sequential sample mean values as a time series whose members are weighted toward the time history of the random variable $x(t)$. With increasing time length of the sample record, each sequential sample mean value is based on more data points than its preceding one. As a result, it is significant to estimate the mean value and standard deviation of this time-history weighted time series since they can be employed to assess the degree of statistical stationarity. These two parameters can furthermore be used to determine those particular segments of a sample period which affect the variation of the random variable. For instance, identification of extreme values of significance can be achieved by means of these two parameters. The mean value $\bar{\mu}$ and standard deviation σ_μ of this time-history weighted time series were estimated by means of Eqs. (6.1) and (6.2) in the form

$$\bar{\mu} = \frac{1}{M} \sum_{k=1}^{M} \mu_k \ , \qquad (6.7)$$

and

$$\sigma_\mu = \left[\frac{1}{M} \sum_{k=1}^{M} (\mu_k - \bar{\mu})^2\right]^{\frac{1}{2}} , \qquad (6.8)$$

where M is the total number of members of this time series, i.e., the total number of sequential sample mean values per a sample period which is exactly the total number of one-minute segments per sample period. To further facilitate the identification of particular segments of interest, incremental mean value and standard deviation were estimated using cumulative increments of five segments, i.e., five-minute segment increments.

6.4 Wind data

The three orthogonal components of the wind U, V and W at each height were estimated by applying the three methods previously outlined. Thus, the following quantities were computed for each wind component:

(1) single sample period mean value (or arithmetic mean) and standard deviation;

(2) one-minute sample averages;

(3) mean value and standard deviation of the time series constructed of the one-minute sample averages;

(4) sequential sample mean values (or sequential averages);

(5) mean value and standard deviation of the time series consisting of the ensemble of sequential sample mean values;

(6) incremental mean value and standard deviation of the ensemble of sequential sample mean values in five-segment increments.

Recall that the notation and sign convention for the U, V and W wind components are shown in Fig. 13 (see Sect. 3.1).

Next, the mean wind in the horizontal plane V_2-i.e., the mean wind in the xy-plane-was estimated. Its speed (or magnitude) was computed according to the relation

$$V_2 = (U^2 + V^2)^{\frac{1}{2}} \quad , \tag{6.9}$$

where U and V are the north-south and east-west wind components, respectively, as portrayed in Fig. 13. The same statistical quantities as for the two wind components were computed for the horizontal mean wind except for the incremental mean value and standard deviation of the ensemble of sequential sample mean values (see item 6 above).

Computation of the single sample period mean value of the horizontal mean wind was moreover carried out in two different ways: (1) based on the single sample period mean values of the two horizontal wind components $\bar{U}$ and $\bar{V}$; and, (2) based on the instantaneous measured values of the two horizontal wind components U_i and V_i. The reason for using these two methods was to point out the effect of the computational method on the expected value. In the first method, the speed of the horizontal mean wind is given by

$$\bar{V}_2 = (\bar{U}^2 + \bar{V}^2)^{\frac{1}{2}} \quad , \tag{6.10a}$$

in which the single sample period mean values of the two horizontal wind components are

$$\bar{U} = \frac{1}{N} \sum_{i=1}^{N} U_i \ , \tag{6.10b}$$

and

$$\bar{V} = \frac{1}{N} \sum_{i=1}^{N} V_i \ . \tag{6.10c}$$

On the other hand, in the second approach,

$$\bar{V}_2 = \frac{1}{N} \sum_{i=1}^{N} V_{2i} \ , \tag{6.10d}$$

where the ith instantaneous value of the horizontal mean wind V_{2i} is given by

$$V_{2i} = (U_i^2 + V_i^2)^{\frac{1}{2}} \ , \tag{6.10e}$$

in which U_i and V_i are the ith instantaneous observed values of the two horizontal wind components.

The direction of the horizontal mean wind with respect to the north-south axis-i.e., the angle α_2 with respect to the x-axis-was further evaluated according to the relation

$$\alpha_2 = \tan^{-1}\left|\frac{V}{U}\right| \ . \tag{6.11a}$$

This direction angle α_2 was computed by the same two different methods as the horizontal mean wind, viz., (1) based on the single sample period mean values of the two horizontal wind component $\bar{U}$ and $\bar{V}$; and, (2) based on the instantaneous observed values of the two horizontal wind components U_i and V_i. In the latter case, the single sample period mean value of the direction angle is given by

$$\bar{\alpha}_{2i} = \frac{1}{N} \sum_{i=1}^{N} \alpha_{2i} \ , \tag{6.11b}$$

where α_{2i} is the ith instantaneous value of the direction angle given by

$$\alpha_{2i} = \tan^{-1}\left|\frac{V_i}{U_i}\right| \ . \tag{6.11c}$$

The azimuth of the horizontal mean wind θ-i.e., the angle measured from North in the clockwise direction in degrees (geographic coordinates)-was further computed according to the following transformations:

for west and south wind ($-V$ and $-U$) and for east and south wind ($+V$ and $-U$), respectively:

$$\theta = 180 \pm \alpha_2 \ , \tag{6.12a}$$

for east and north wind ($+V$ and $+U$):

$$\theta = \alpha_2 \ , \tag{6.12b}$$

and for west and north wind ($-V$ and $+U$):

$$\theta = 360 - \alpha_2 \ . \tag{6.12c}$$

The total mean wind W_3-i.e., the resulting wind of the horizontal mean wind V_2 and the vertical wind W-was next computed by means of the relationship

$$\bar{W}_3 = (\bar{V}_2^2 + \bar{W}^2)^{\frac{1}{2}} \ . \tag{6.13}$$

Only the single sample period mean value of the total mean wind $\bar{W}_3$ based on the single sample period mean values of its two components $\bar{V}_2$ and $\bar{W}$ was evaluated. The elevation of the total mean wind ϕ-i.e., the angle of the total mean wind $\bar{W}_3$ with respect to the horizontal plane (xy-plane)-was estimated according to the relation

$$\bar{\phi} = \tan^{-1}\left(- \frac{\bar{W}}{\bar{V}_2}\right). \tag{6.14}$$

Note that this relationship gives the single sample period mean value of the elevation in degrees. A positive elevation indicates an upward vertical wind W according to the sign convention portrayed in Fig. 13.

In order to describe the wind variation with height, the three wind components U, V and W, the horizontal mean wind V_2, and the total mean wind W_3 were referred to their corresponding values measured at canopy top. Thus, the normalized wind is given by

$$\tilde{\bar{U}}_i = \bar{U}_i/|\bar{U}_{ih}| \ , \tag{6.15}$$

where U_i stands for any wind component, U_{ih} is the corresponding reference wind component at canopy top and the tilde (˜) denotes dimensionless value. The absolute value of the reference wind was used in order to preserve the direction of the wind components. Computation of the normalized wind was solely conducted for the single sample period mean values of: (1) the three mean wind components $\bar{U}$, $\bar{V}$ and $\bar{W}$; (2) the horizontal mean wind $\bar{V}_2$; and, (3) the total mean wind $\bar{W}_3$.

The standard deviation of the wind is generally viewed as representative of the magnitude of the fluctuating wind (or turbulent wind) in the same direction as the mean wind. In other words, the standard deviation is considered as being equivalent to the rms value of the turbulent wind. Computation of the single sample period standard deviation of each wind component σ_i was carried out using Eq. (6.2). Since this standard deviation was computed for all the three components of the wind at each height, the corresponding components of the turbulent wind were obtained. The direction of the turbulent wind was assigned in each case according to the direction of the mean wind. In order to describe the variation with height of the turbulent wind, the three components of the turbulent wind were referred to their corresponding absolute values at canopy top in a similar manner as for the mean wind. Thus, the normalized turbulent wind is expressed by

$$\tilde{\sigma}_i = \sigma_i / |\sigma_{ih}| , \qquad (6.16)$$

where σ_i denotes any component of the turbulent wind, σ_{ih} is the corresponding turbulent wind component at canopy top and the tilde stands for dimensionless value.

The turbulence intensity of each turbulent wind was computed, as customarily done, by referring the turbulent wind to its corresponding mean wind. As a result, the turbulence intensity of any turbulent wind Tu_i is given by

$$Tu_i = \sigma_i / \bar{U}_i , \qquad (6.17)$$

where $\bar{U}_i$ is the single sample period mean value of the corresponding mean wind.

The turbulent wind in the horizontal plane σ_2, i.e., the turbulent wind in the xy-plane, was next computed by means of the relation

$$\sigma_2 = (\sigma_u^2 + \sigma_v^2)^{1/2} , \qquad (6.18)$$

where σ_u and σ_v are the two horizontal components of the turbulent wind, i.e., the U- and V-component. Estimation of the direction of the horizontal turbulent wind with respect to the north-south axis and of its azimuth was accomplished, as for the horizontal mean wind, by means of Eqs. (6.11a) and (6.12), respectively.

6.5 Temperature data

In this experiment the dry- and wet-bulb temperatures, T_d and T_w, were monitored at each height as previously mentioned in Sect. 3.1. In estimating their values by means of the methods previously outlined, the following quantities were computed:

(1) single sample period mean value (or arithmetic mean) and standard deviation;

(2) one-minute sample averages;

(3) mean value and standard deviation of the time series constructed of the one-minute sample averages.

The sequential sample mean values were not computed since the difference between the single sample period mean value and that of the one-minute averages time series was completely negligible, viz., less than 1%.

The potential temperature, which is a parameter of interest with regard to the stability of the atmosphere, was computed. Since the measurement of temperature was conducted up to a height of 22.9 m, the potential temperature θ was approximated, as commonly done for the surface boundary layer up to a depth of about 100 m [4,5], by the relationship

$$\theta = T_d + \Gamma z. \tag{6.19}$$

In this equation, T_d is the actual dry-bulb temperature, z denotes the height in m and Γ stands for the dry adiabatic lapse rate which is equal to 0.0098°C/m (0.00537°F/ft) [4]. Both potential and dry temperatures are in degrees centigrade in the foregoing relationship. Computation of the potential temperature was conducted using the single sample period mean value of the measured dry temperature. The vertical temperature gradient or environmental lapse rate was further computed for both the actual dry and potential temperatures, i.e., $\Delta T_d/\Delta z$ and $\Delta\theta/\Delta z$. A layer is stable when $|\Delta T_d/\Delta z| < \Gamma$ or $\Delta\theta/\Delta z > 0$ and unstable when $|\Delta T_d/\Delta z| > \Gamma$ or $\Delta\theta/\Delta z < 0$.

The relative humidity was computed according to the relationship

$$\phi = e/e_s , \tag{6.20}$$

where e is the partial vapor pressure in the air-vapor mixture and e_s designates the saturation vapor pressure over water at given dry-bulb temperature. It is important to remark that the relative humidity approximated by the foregoing equation is within at most 2.5% of its true value under extreme conditions of about 50% relative humidity and high temperature of the order of 50°C. Under normal conditions-viz., temperature of about 10°C and 50% relative humidity-the difference is about 0.5% [6]. The partial vapor pressure is given by [6]

$$e = e' - \Delta e \ , \tag{6.21}$$

in which e' is the saturation vapor pressure at the wet-bulb temperature, and the correction

$$\Delta e = [0.000660(1 + 0.00115T_d)]p(T_d - T_w) \ , \tag{6.22}$$

where the dry- and wet-bulb temperatures, T_d and T_w, are in degrees centigrade, p is the barometric pressure in mb and e, e' and Δe are in the same units as the barometric pressure, viz., in mb. Computation of the saturation vapor pressures at the dry- and wet-bulb temperatures (e_s and e') was accomplished by means of 6th degree polynomial [7] which is accurate within 1% in the temperature range from -50 to +50°C. This 6th degree polynomial is given by

$$e = \sum_{n=0}^{6} a_n T^n \ , \tag{6.23}$$

where $e = e_s$ when $T = T_d$ and $e = e'$ when $T = T_w$. In the foregoing equation, the temperature is in degrees centigrade and the saturation vapor pressure in mb. The numerical values of the coefficients a_n are [7]: $a_0 = 6.107799961$, $a_1 = 4.436518521 \times 10^{-1}$, $a_2 = 1.428945805 \times 10^{-2}$, $a_3 = 2.650648471 \times 10^{-4}$, $a_4 = 3.031240396 \times 10^{-6}$, $a_5 = 2.034080948 \times 10^{-8}$ and $a_6 = 6.136820929 \times 10^{-11}$.

The dew-point temperature T_{dp} of moist air, which is the temperature at which the vapor condenses when the air-vapor mixture is cooled at constant pressure, was estimated by means of the following empirical relationship (Atmospheric Science Dept., CSU):

$$T_{dp} = T_d - (1 - \phi)^7(16.65 + 0.118T_d) - (1 - \phi)^2(3.14 + 0.01465T_d)^2$$
$$-(1 - \phi)(13.4 + 0.103T_d) \ , \tag{6.24}$$

where the dew-point temperature T_{dp} and dry-bulb temperature T_d are in degrees centigrade and ϕ is the relative humidity. In estimating the relative humidity and the dew-point temperature, same quantities as for the dry- and/or wet-bulb temperature were computed, viz.,

(1) single sample period mean value (arithmetic mean) and standard deviation;

(2) one-minute sample averages;

(3) mean value and standard deviation of the time series constructed of the one-minute sample averages.

The relative humidity and the dew-point temperature were computed, instead of using tables, in view of the large volume of data and the various parameters that were estimated. An excellent agreement among the computed values of relative humidity and dew-point temperature (single sample period mean values) and those obtained from standard psychrometric tables at the same dry- and wet-bulb temperatures was consistently found.

6.6 Solar radiation data

Total solar radiation-i.e., direct and diffuse-was monitored at ground level and at tower top as described in Sect. 3.1. In estimating the total solar radiation, the following quantities were computed:

(1) single sample period mean value (or arithmetic mean) and standard deviation;

(2) one-minute sample averages;

(3) mean value and standard deviation of the time series constructed of the one-minute sample averages;

(4) sequential sample mean values (or sequential averages);

(5) mean value and standard deviation of the time series consisting of the ensemble of sequential sample mean values.

6.7 Tethersonde balloon data

Reduction of the data measured by the balloon airborne package was conducted on-line by means of a microprocessor incorporated in the balloon ground package as previously mentioned in Sect. 3.2. The following quantities were computed and recorded on paper tape:

(1) starting time of each 30 s record;

(2) height in m;

(3) pressure in mb;

(4) dry temperature in degrees centigrade;

(5) relative humidity;

(6) mixing ratio (or specific humidity);

(7) wind speed in the horizontal plane;

(8) wind direction (azimuth) in the horizontal plane;

(9) potential temperature in degrees kelvin.

7. DATA PROCESSING

A major effort was devoted to the development of a set of special- and general-purpose computer programs (or codes) and plotting routines for efficient and expedient processing of the amassed data. Processing of the data included two basic phases: (1) data preparation and (2) data reduction. Both these phases were accomplished by means of suitable computer codes.

7.1 Data preparation

Preparation of the raw data for reduction consisted of: (1) data editing; (2) data conversion; and, (3) data preprocessing. Data editing is a preanalysis procedure which involved the following four steps:

(1) reading of the digital data recorded on magnetic tape;

(2) rejection of whatever information was recorded on the shorted channels of the data logger, viz., channel no. 10 and channels no. 29 to 60 (see Appendix I.1);

(3) retrieval of the data records which were recorded on the 27 live channels of the data logger, viz., channels no. 1 to 9 and 11 to 28 (see Appendix I.1); and

(4) elimination of degraded and/or spurious signals.

Three special-purpose computer codes were developed to accomplish the data editing.

To start with, a relatively simple and efficient program for the read-in and storage on disk of the data recorded on tape was developed. The read-in of the data revealed that its format was not consistent and, consequently, not suitable for reduction by means of a digital computer. This resulted from a slight unsynchronization among the data logger timer, printer and digital tape recorder. The digital tape recording was continuously conducted while the printer was turned on at selected time intervals of 1, 2 or 5 minutes. Whenever the timer activated the printer, the digital tape recording was instantaneously interrupted and a new data record was initiated. This sudden cutoff occurred randomly before and after the first 27 channels of significant data were recorded and even within a single word. As a result, the format of the data records-i.e., channel recording order-changed randomly any time the printer went on. This random format change constituted a major difficulty in retrieving the data records in a consistent format required to identify each piece of data. It was therefore necessary to reformat all the data. This reformatting consisted of: (1) rejection of these particular data records that were cut off by the printer prior to completing the recording of the first 27 channels of significant data; and, (2) rearrangement of the words in each data record in a consistent and readable format.

In order to achieve this reformatting, a special-purpose computer code of quite major size was developed. This effort was highly time consuming because of the inherent complexity of the program and the computer time required to reformat all the digital data recorded during the blast tests which amounted to a total of 38 hours. This special-purpose program counted and identified each individual character, verified the structure and content of each word, rejected these partial data records consisting of less than the first 27 channels of significant data, and rearranged the words within each one-minute data record in a consistent and suitable format for reduction. In addition, this code eliminated the shorted channels data (channels no. 10 and 29 to 60). Comparison of the reformatted data with the original data indicated that the time length of the rejected data records containing significant data amounted to less than 10 minutes out of a total of 38 hours of recorded data. It is important to remark that the restructuring of the format, which was a major aspect of this program, was an indispensable prerequisite for the subsequent reduction of the data by a digital computer.

A thorough check of the data was next carried out in order to detect any degraded and/or spurious signals. Such signals commonly result from malfunction of the sensor and/or the data logger, excessive noise, human operational errors and overloading. A special-purpose computer code was devised to identify, reject and replace such signals with legitimate data. Any spurious signal was replaced by its immediate preceding data point. Identificaton of any overloaded signal was accomplished by prescribing an amplitude threshold for each instrument. As far as the UVW anemometers are concerned, an amplitude threshold of 22.35 m/s (50 mph) was used since this is their maximum dynamic response (see Sect. 3.1) In the case of thermocouples, any reading larger than its preceding data point by more than 25% was discarded. Similarly, any pyranometer read-out greater than one solar constant (1.99 Ly/min) was rejected. Any overloaded signal was next replaced by the average of its immediate preceding and succeeding good data points. Note that the time interval between two consecutive signals of any particular sensor was 5 s (or 25 s when the printer was on; see Sect. 4.1). The total number of data points rejected amounted to about 8000,which was completely insignificant compared with the total number of data points which was about 1.12752×10^6.

With the completion of the data editing, the data conversion was carried out as follows:

(1) correction for the data logger channel offset described in Appendix I.1 (Sect. I.1.1);

(2) conversion of the anemometers and pyranometers output signals from electrical units into corresponding physical units according to their calibrations outlined in Appendix I.1 (Sect. I.1.2);

(3) correction of the anemometers output signals for their non-cosine response according to the method advanced in Refs. 8 & 9.

A computer program was specifically constructed to accomplish the data conversion. The algorithm for the non-cosine response correction of each propeller anemometer reported in Refs. 8 & 9 was incorporated in the present conversion computer code.

The data preprocessing consisted of:

(1) partitioning of the data into (i) pre-blast, (ii) post-blast and (iii) quiet period (no blast) parts;

(2) creation of permanent files for these parts;

(3) recording of the data on archive tape for later use.

A special-purpose computer code was devised to achieve this data preprocessing.

7.2 Data reduction

A general-purpose computer program was developed for conducting the data reduction by means of the methods outlined in Sect. 6. This code consisted of a set of subroutines, each one devoted to computing a single quantity, in order to ensure its efficiency and versatility. As a matter of fact, this program was devised so that it can be used for similar data without any major modification. Plotting routines were also constructed in order to efficiently and expediently obtain computer graphs of all the results. Full documentation of this general-purpose code and associated plotting routines is not given here since it is beyond the scope of the present report. However, publication of a report on this general-purpose code, the plotting routine and the special-purpose programs related to data preparation is contemplated provided that the necessary support will be available.

All the programs were written in FORTRAN Extended Version 4 and executed using a Cyber 172 computer (Control Data Corp.). The plotting was conducted employing a Versatec electrostatic plotter (Versatec, Xerox Corp.) and the plotting routines were written according to Versaplot-07 software.

8. RESULTS

Reduction of the meteorological data within and above a forest canopy was, as earlier stated, the prime objective of this work. At the present time, no analysis and interpretation of the reduced data has been conducted. Such an analysis is, as a matter of fact, beyond the scope of the present program. However, all the necessary efforts to ensure the necessary support and conditions for conducting an in-depth analysis of the reduced data are being undertaken.

The data amassed during the blast tests includes:

(1) 38 h of on-line digitized data on the three components of the wind, dry- and wet-bulb temperatures at five heights within the forest canopy;

(2) 38 h of on-line digitized data on the total solar radiation at ground level and canopy top;

(3) 1 h 45 min of balloon sounding above the forest canopy;

(4) 23 h 30 min of analog data on the turbulence at two heights within the forest canopy measured by means of hot-wire anemometers.

In addition, the data gathered during the quiet period (no blast test)-i.e., background meteorological data-includes:

(1) 20 h of on-line digitized data on the three components of the wind, dry- and wet-bulb temperatures at five heights within the forest canopy;

(2) 20 h of on-line digitized data on total solar radiation at ground level and canopy top;

(3) 1 h 5 min of balloon sounding data above the forest canopy;

(4) 19 h of analog data on turbulence at two heights within the forest canopy by means of hot-wire anemometers.

Thus, totals of 58 h of digitized data, 2 h 50 min of balloon sounding data and 42 h 30 min hours of analog data were collected. The reason for amassing such a large volume of data, which far exceeded the initial planning, were the prevailing experimental conditions and the nearly flawless operation of the instruments and the data acquisition system. It is apparent that reduction of such a large amount of data was not feasible within the inherent time and financial constraints of this program. As a result, only the following parts of the data collected during the blast tests were reduced:

(1) 20 h 59 min of digital data on wind, temperatures and total solar radiation for 27 blast tests divided into pre- and post-blast sample periods for each test as outlined in Table 3 (see Sect. 5.1);

(2) 1 h 4 min of balloon sounding data in conjunction with 9 blast tests as summarized in Table 5.1 (see Sect. 5.3).

Similarly, these parts of the background meteorological data that were reduced are:

(1) 6 h 30 min of digitized data on wind, temperatures and total solar radiation as tabulated in Table 4 (see Sect. 5.2);

(2) 1 h 5 min of balloon sounding data as outlined in Table 5.2 (see Sect. 5.3).

Reduction of the balance of the data is planned but its completion is contingent upon ensuring the necessary time and manpower support.

The results are presented in tabular form in 1422 data tables and in graphical form in 1795 figures. These data tables and figures are given in eight appendixes in view of their large number and in order to readily identify each case. A list of these eight appendixes including their title and cross-reference to the test sequence tables (see Tables 3, 4, 5 in Sects. 5.1, 5.2 and 5.3, respectively) is given in Table 7 below.

TABLE 7. LIST OF APPENDIXES

Appendix No.	Title	Test Sequence Table No.
II	Pre- and Post-Blast Results Data Tables	3
III	Pre- and Post-Blast Results Figures	3
IV	Tethersonde Balloon Surveys Data Tables	5.1
V	Tethersonde Balloon Surveys Figures	5.1
VI	Background Meteorological Data Data Tables	4
VII	Background Meteorological Data Figures	4
VIII	Background Tethersonde Balloon Surveys Data Tables	5.2
IX	Background Tethersonde Balloon Surveys Figures	5.2

Each case is indexed in these appendixes according to the test code given in the test sequence tables.

8.1 Meteorological tower results

The results of the measurements performed by means of the instrumented meteorological tower are reported in data tables in Appendix II for the blast tests and in Appendix VI for the background data (quiet period). All the corresponding figures are given in Appendixes III and VII, respectively. The contents of the appendixes in which the data tables are given (II & VI) and that of the appendixes in which the figures are presented (III & VII) are identical since similar data obtained under different ambient conditions is reported therein. In order to gain insight into the data tables and figures given in these four appendixes, their contents is outlined in Table 8 below. The heading of each data table in the computer print-out, the title of each data table as given in the list of contents of each appendix, the definition of each quantity, the equation used in computing each quantity and cross-reference to the corresponding figures whenever applicable, are summarized in Table 8. Documentation of the codes for various terms used in the computer print-out and in the computer-produced figures is further given in Appendix I.2 for the sake of facilitating the identification of the various data tables and figures. Note that the data tables and the figures are presented in these appendixes in chronological order without being identified by a number.

TABLE 8. CONTENTS OF APPENDIXES II, III, VI AND VII

WIND DATA

No.	Table Heading (computer print-out)	Title (Apps. II, VI)	Quantity	Eq. No.	Fig. No.
1	Arithmetic mean	North/South U, East/West V, Downward/Upward W, mean wind--sample arithmetic mean	Single sample period mean values of U,V,W	6.1	
2	Normalized	North/South U, East/West V, Downward/Upward W, normalized mean wind--sample arithmetic mean	Normalized single sample period mean values of U,V,W	6.15	
3	rms	North/South U, East/West V, Downward/Upward W, turbulent wind rms value (wind standard deviation)	Single sample period standard deviation of U,V,W	6.2	
4	Normalized	North/South U, East/West V, Downward/Upward W, normalized turbulent wind rms value (wind standard deviation)	Normalized single sample period standard deviation of U,V,W	6.16	

TABLE 8. (CONTINUED)

No.	Table Heading (computer print-out)	Title (Apps. II, VI)	Quantity	Eq. No.	Fig. No.
5	Turbulence intensity	North/South U, East/West V, Downward/Upward W, turbulence intensities	Turbulence intensity based on single sample period mean values of U,V,W	6.17	
6	2-D rms vector	Turbulent wind rms value (speed & direction) in the horizontal plane mean values of U and V; and its azimuth	Turbulent wind based on single sample period standard deviations of U and V; and its azimuth	6.18 6.12	14
7	One minute averages	North/South U, East/West V, Downward/Upward W--one-minute average	(1) One-minute sample averages of U,V,W	6.3	1 3 5
	Mean		(2) Mean value of the ensemble of one-minute sample averages	6.4	
	STDV		(3) Standard deviation, as above	6.5	
8	Sequential averaging	North/South U, East/West V, Downward/Upward W--sequential average	(1) Sequential sample mean values of U,V,W	6.6	2 4 6
	Mean		(2) Mean of the ensemble of sequential sample mean values	6.7	
	STDV		(3) Standard deviation, as above	6.8	
9	Sequential average over N minutes NSEQAV	North/South U, East/West V, Downward/Upward W--sequential average over varying sample size N	(1) Sequential sample mean value over five-minute segment increments	6.6	
	Mean		(2) Mean value of the ensemble of sequential sample mean values over five-minute segment increments	6.7	
	STDV		(3) Standard deviation, as above	6.8	

TABLE 8. (CONTINUED)

No.	Table Heading (computer print-out)	Title (Apps. II, VI)	Quantity	Eq. No.	Fig. No.
10	Mean wind vectors in the X-Y plane Arithmetic mean Normalized	Mean and normalized mean wind (speed & direction) in the horizontal plane	Single sample period mean value of the horizontal wind V_2, its normalized value and its azimuth (called direction in Fig. 13) based on single sample period mean values of the horizontal wind components U and V (Table 1) - 1st method, Sect. 6.4	6.10a 6.10b 6.10c 6.15 6.11a 6.12	11 12 13 15
11	Mean wind vectors in the X-Y plane Arithmetic mean of instantaneous vectors Normalized	Mean and normalized mean instantaneous wind (speed & direction) in the horizontal plane	Single sample period mean value of the horizontal wind V_2, its normalized value and its azimuth based on the instantaneous values of the horizontal wind components U and V - 2nd method, Sect. 6.4	6.10d 6.10e 6.15 6.11b 6.11c 6.12	16
12	Mean velocity vectors in 3-D Arithmetic mean Normalized	Mean and normalized mean wind (speed & direction) in space	Single sample period mean value of the total wind W_3, its normalized value and its declination based on single sample period mean values of the horizontal wind V_2 (Table 10) and vertical wind W (Table 1)	6.13 6.10a (for V_2) 6.1 (for W) 6.15 6.14	
13	One minute averages	Mean wind in horizontal plane (speed & direction)--one-minute averages	(1) One-minute sample averages of the mean wind V_2 in the horizontal plane (xy plane) and its its azimuth (called direction in Fig. 9) based on the instantaneous values of U and V;	6.10d 6.10e 6.3 6.11b 6.11c 6.12	7 9
	Mean		(2) Mean value of the ensemble of one-minute sample averages	6.4	
	STDV		(3) Standard deviation, as above	6.5	

TABLE 8. (CONTINUED)

No.	Heading (computer print-out)	Table Title (Apps. II, VI)	Quantity	Eq. No.	Fig. No.
14	Sequential averaging	Mean wind in the horizontal plane (speed & direction)--sequential average	(1) Sequential sample mean values of the mean wind V_2 in the horizontal plane (xy-plane) and its azimuth (called direction in Fig. 10) based on the instantaneous values of U and V	6.10d 6.10e 6.6 6.11b 6.11c 6.12	8 10
	Mean		(2) Mean of the ensemble of sequential sample mean values	6.7	
	STDV		(3) Standard deviation, as above	6.8	
		TEMPERATURE DATA			
15	Arithmetic mean	Vertical profile of the dry- and wet-bulb mean temperature	Single sample period mean values of dry- and wet-bulb temperatures	6.1	21 22
		Vertical profile of the potential temperature	Single sample period mean values of potential temperature	6.1 6.19	
		Vertical profile of the dew point and relative humidity	Single sample period mean values of dew-point temperature and relative humidity	6.1 6.24 6.20	23 24
		Vertical profile of the dry- and wet-bulb temperature standard deviation	Single sample period standard deviation of dry- and wet-bulb temperature	6.2	
16	Vertical temperature gradients	Vertical gradient of the dry-bulb and potential temperature	Single sample period mean values of dry-bulb and potential temperature gradients		
18	One minute averages	Dry- and wet-bulb temperature--one-minute average	(1) One-minute sample averages of dry and wet-bulb temperatures	6.3	17 18
	Mean		(2) Mean value of the ensemble of one-minute sample averages	6.4	
	STDV		(3) Standard deviation, as above	6.5	

TABLE 8. (CONTINUED)

No.	Heading (computer print-out)	Table Title (Apps. II, VI)	Quantity	Eq. No.	Fig. No.
19	One minute averages	Dew point temperature and relative humidity--one-minute average	(1) One-minute sample averages of dew-point temperature and relative humidity	6.24 6.20 6.3	19 20
	Mean		(2) Mean value of the ensemble of one-minute sample averages	6.4	
	STDV		(3) Standard deviation, as above	6.5	
		RADIATION DATA			
17	Total solar radiation, Mean and STDV	Total solar radiation--sample mean and standard deviation	Single sample period mean value and standard deviation of total solar radiation	6.1 6.2	
20	One minute average	Total solar radiation--one-minute and sequential average	(1) One-minute sample averages of total solar radiation	6.3	25
	Mean		(2) Mean value of the ensemble of one-minute sample averages	6.4	
	STDV		(3) Standard deviation, as above	6.5	
	Sequential averaging		(1) Sequential sample mean values of total solar radiation	6.6	
	Mean		(2) Mean value of the ensemble of sequential sample mean values	6.7	
	STDV		(3) Standard deviation, as above	6.8	
		SAMPLE PERIOD RECORD			
21	Minute records	Number and time of records in each minute of data	Data records in the sample period		

Appendix III, in which the figures of the pre- and post-blast results are given, is divided into five sections for convenience's sake. Each section, which consists of 25 identical figures, corresponds to one single day of measurement. In each figure presented in Appendixes III and VII, the following relevant information is incorporated: (1) the date of the experiment; (2) the sample period time length; (3) the experiment conditions, viz., pre-blast, post-blast or background data; and, (4) the particular variable depicted. In these figures in which the variation with time of the wind (Figs. 1-10), temperature (Figs. 17-19), relative humidity (Fig. 20) and total solar radiation (Fig. 25) are portrayed, the following additional information is given: (1) the measurement height; (2) mean value and standard deviation according to each particular computation. In addition, in all the figures in which the wind components are shown, the sign convention of the Gill UVW anemometer is indicated (Figs. 1-6). In these figures, in which vertical profiles of various parameters are depicted (Figs. 11-14 & 21-24), the base of the crown is denoted as canopy bottom and the canopy top is indicated. In the wind roses given in Figs. 15 & 16, the horizontal wind vector points radially outward to the direction from which the wind was blowing, i.e., the wind azimuth. The wind rose portrayed in Fig. 15 is based on the single sample period mean values of the two horizontal wind components (1st method, Sect. 6.4) while that shown in Fig. 16 on the instantaneous values of the horizontal wind components (2nd method, Sect. 6.4). Inspection of these two wind roses clearly indicates that the method of computation affects the result. An analysis for determining what method is more appropriate has been initiated.

8.2 Tethersonde balloon results

All the results of the tethersonde balloon sounding are provided: (1) in data tables in Appendix IV and in figures in Appendix V for the blast tests; and, (2) in data tables in Appendix VIII and in figures in Appendix IX for the background conditions (quiet period). The contents of the appendixes in which the data tables are given (IV & VIII) and that of the appendixes in which the figures are shown (V & IX) are identical since the data is similar except for the ambient conditions. Contents of these four appendixes is outlined in Table 9 below for the sake of gaining insight into the data tables and figures presented.

In each figure, the canopy top is indicated for convenience. The wind rose shown in Fig. 4 was split up into several figures for clarity's sake. No more than ten wind vectors are depicted in each wind rose. The horizontal wind vector points radially outward to the direction from which the wind is blowing-i.e., the wind azimuth-as in the wind roses for the meteorological tower results. Documentation of the codes used in the computer print-out and in computer-produced figures is provided in Appendix I.2.

TABLE 9. CONTENTS OF APPENDIXES IV, V, VIII AND IX.

Table Heading (Computer Print-out)	Quantity	Figure No.
Time	Sampling time (CST)	Given
Z	Height above ground	Given
PRESS	Barometric pressure	1
TEMP	Dry-bulb temperature	5
RH	Relative humidity	7
MIX RATIO	Mixing ratio	8
WIND SPEED	Wind speed in the horizontal plane	2,4
WIND DIR	Wind direction (or azimuth)	3,4
POT TEMP	Potential temperature	6

8.3 Sample of results

In order to gain insight into the results, samples of three selected sample periods are incorporated herein. Results of a single post-blast sample period (Test Code 27-C9-AB, see Table 3), a single tethersonde balloon sounding during blast tests (Test Code 27-C9-AB, see Table 5.1), and a single background meteorological data sample period (Test Code BMD-24-6, see Table 4) are given in Supplements I, II and III, respectively. The figures, in which the results are displayed, are presented in these three supplements as outlined in Tables 8 and 9. They are given in the same order as in Appendixes III, V and VII.

These three sample periods were selected based on the prevailing wind direction, the canopy fetch upwind of the tower and their time length. During the post-blast and balloon sample periods, the wind was from about 165 to 238° (SSE to SSW) whereas during the background data sample period the prevailing wind was from about 120 to 156° (ESE to SSE). The upwind canopy fetch consists of coniferous trees and mixture of coniferous and deciduous trees in the former cases. In the latter case, the approaching canopy fetch consists of conferous trees. The time lengths of the post-blast, balloon sounding and background data sample periods were 30, 14 and 30 min, respectively.

9. CONCLUDING REMARKS

A field investigation of the micrometeorological parameters within and above a forest canopy and, in particular, the reduction of the collected data are described in this report. The field measurements were conducted in conjunction with the Atmospheric Sciences Laboratory Dusty Infrared Test IIIA (DIRT IIIA) at Fort Polk, Louisiana, from 14 to 25 April 1980. Measurement of the three orthogonal components of the wind, dry- and wet-bulb temperatures and total solar radiation inside the forest canopy was carried out by means of an instrumented meteorological tower. Turbulence inside the forest canopy was monitored using hot-wire anemometers. Surveys of the meteorological parameters above the forest canopy were performed by means of a tethersonde balloon. The measurements were primarily conducted during the DIRT IIIA blast tests. In addition, the background meteorological conditions-i.e., during no blast tests (quiet period)-were surveyed. Totals of 58 h of meteorological tower data, 2 h 50 min of balloon data and 42 h 30 min of hot-wire data were collected.

The reduction of the extremely large amount of amassed data was beyond the objective and resources of this program. To date, 20 h 59 min of meteorological tower data and 1 h 45 min of balloon data during the blast tests, and 6 h 30 min of meteorological tower data and 1 h 5 min of balloon data durng the quiet period (no blast tests) were reduced. Reduction of the balance of the data is planned but its completion depends upon securing the necessary support.

In reducing the data, three different statistical methods were used. Single sample period values, one-minute sample averages and sequential sample values were computed. In applying these methods, the mean value and standard deviation of the meteorological parameters were computed. The results are tabulated in 1422 data tables and partially displayed in 1795 figures. Samples of the results for a single post-blast sample period, a single tethersonde balloon sounding during the blast tests, and a single background meteorological data sample period are presented in Supplements I, II and III, respectively, to gain insight into how the results are reported. In processing the data, several special-purpose and general-purpose computer programs were developed. These computer codes can be used to reduce similar data without any major modifications. Documentation of these computer programs is, however, contingent upon ensuring the necessary resources.

The one-minute sample averages and the sequential sample values were advanced in order to construct time series of the various meteorological parameters. Such time series can efficiently be used to conduct advanced statistical analyses of the data. Specifically, these time series can be utilized to perform probability, correlation and spectral analyses, to estimate the degree of statistical stationarity of the data and to determine the corresponding time scales, and to identify extreme values of significance. Such analyses, which are of prime importance, were unfortunately beyond the tasks of the present limited program.

In view of the available data, the following suggestions for future work are worthy of earnest consideration:

(1) Completion of the data reduction.

(2) Documentation of the various special-purpose and general-purpose computer programs developed within the context of this program because of their potential application in similar field studies.

(3) Statistical analyses of the meteorological data along the lines outlined above which can provide invaluable insight into the flow within and above a forest canopy. Results of such statistical analyses can immediately be applied to mission-oriented cases and, moreover, can be used as data base for analytical and/or numerical modeling of airflow in a forest canopy.

All the necessary efforts to secure the support for undertaking these proposed studies are being pursued.

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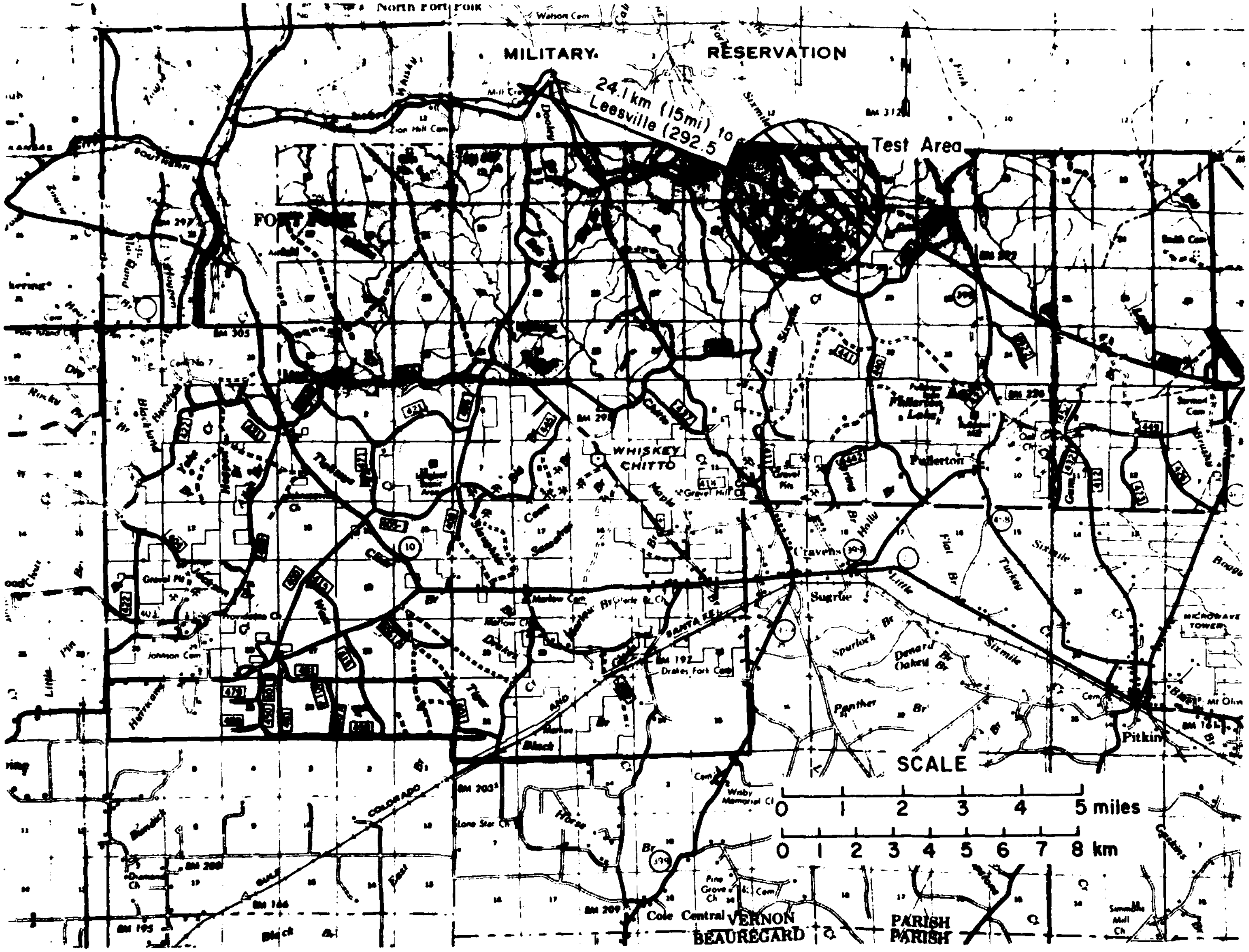


Fig. 1 Regional topographic map of Fort Polk, Louisiana, in which the test area is indicated.

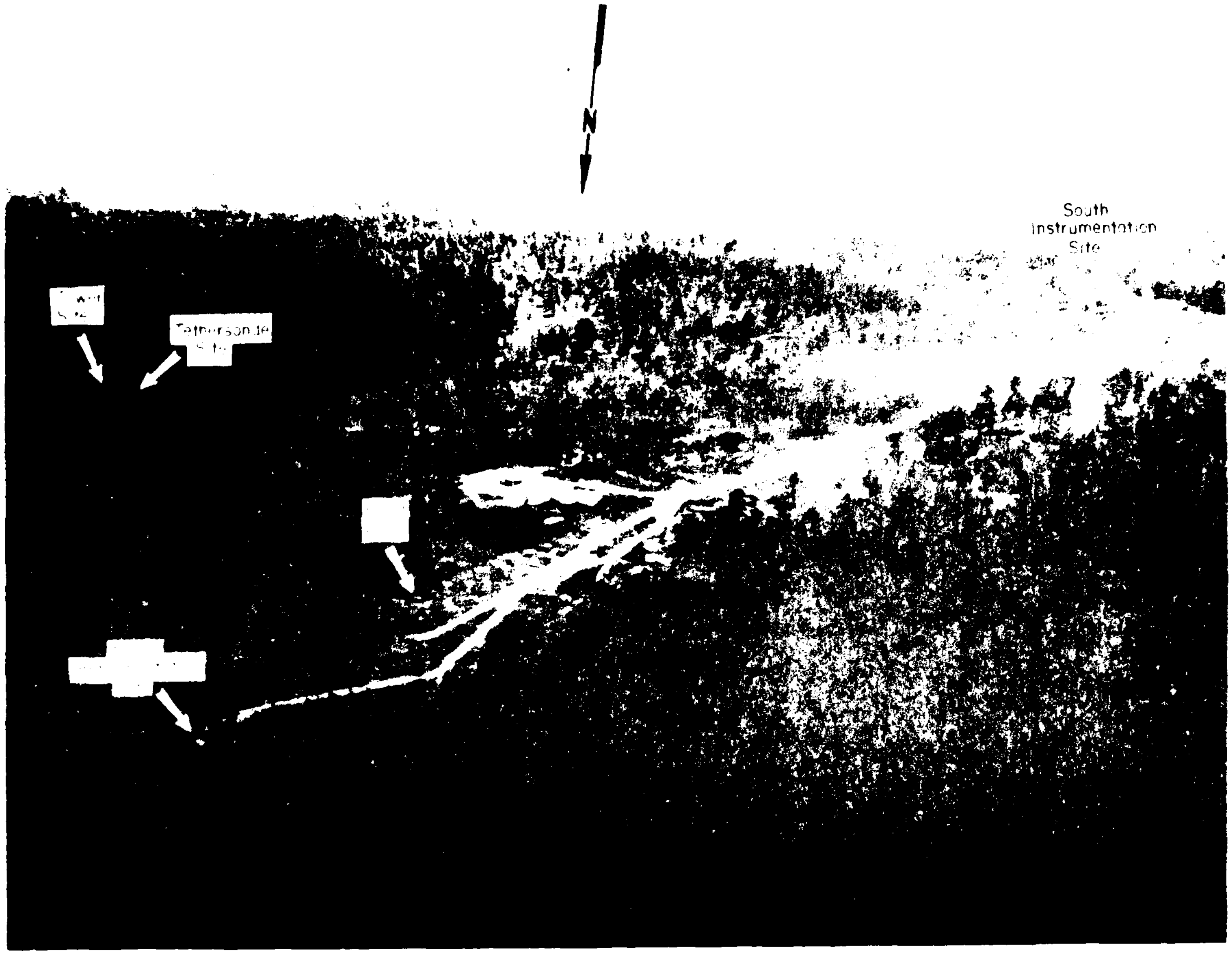


Fig. 2 Aerial photograph of the forest canopy and test sites.

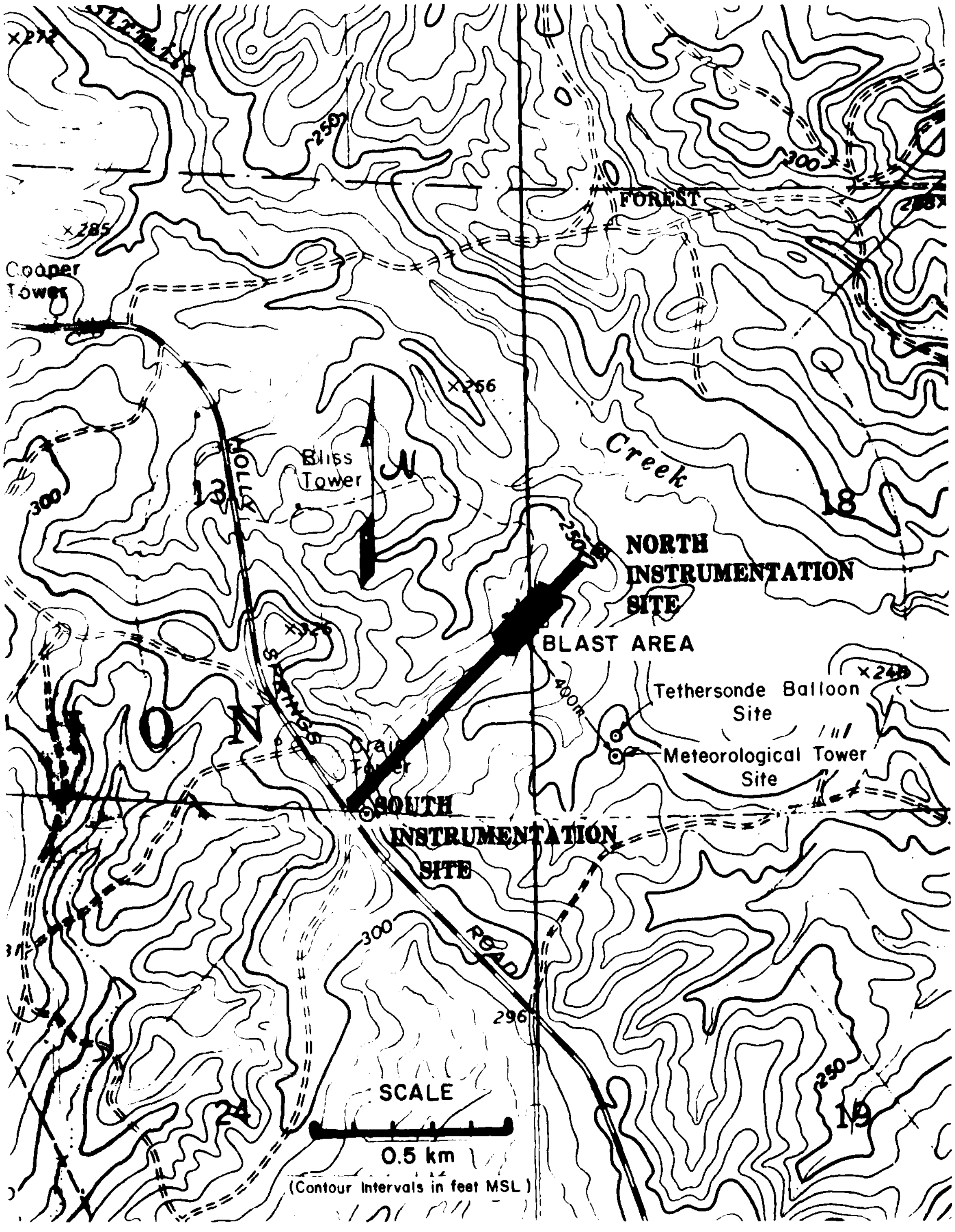


Fig. 3 Topographic map of the blast area, meteorological tower and tethersonde balloon sites.

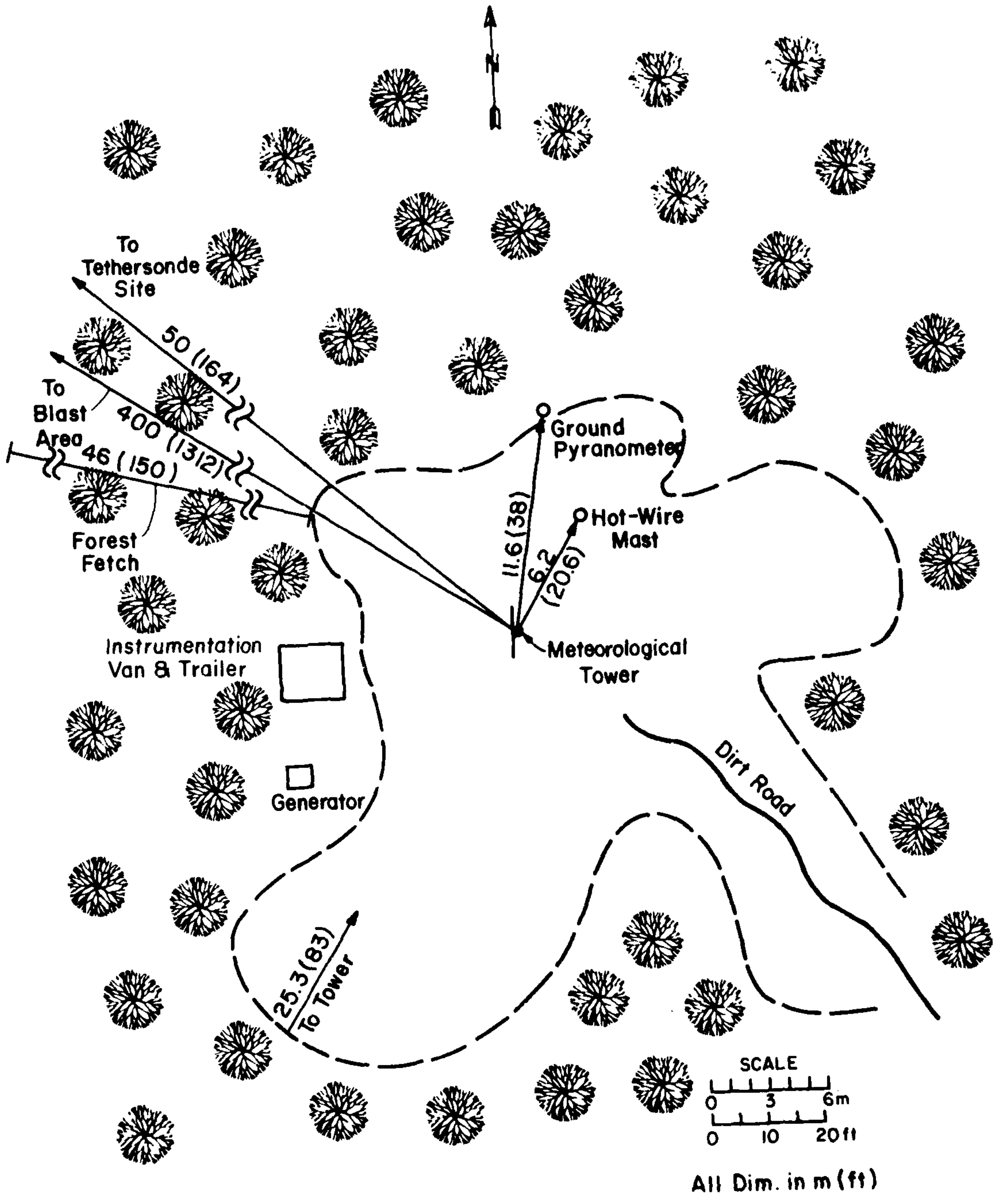


Fig. 4 Plan view of the meteorological tower site clearing.

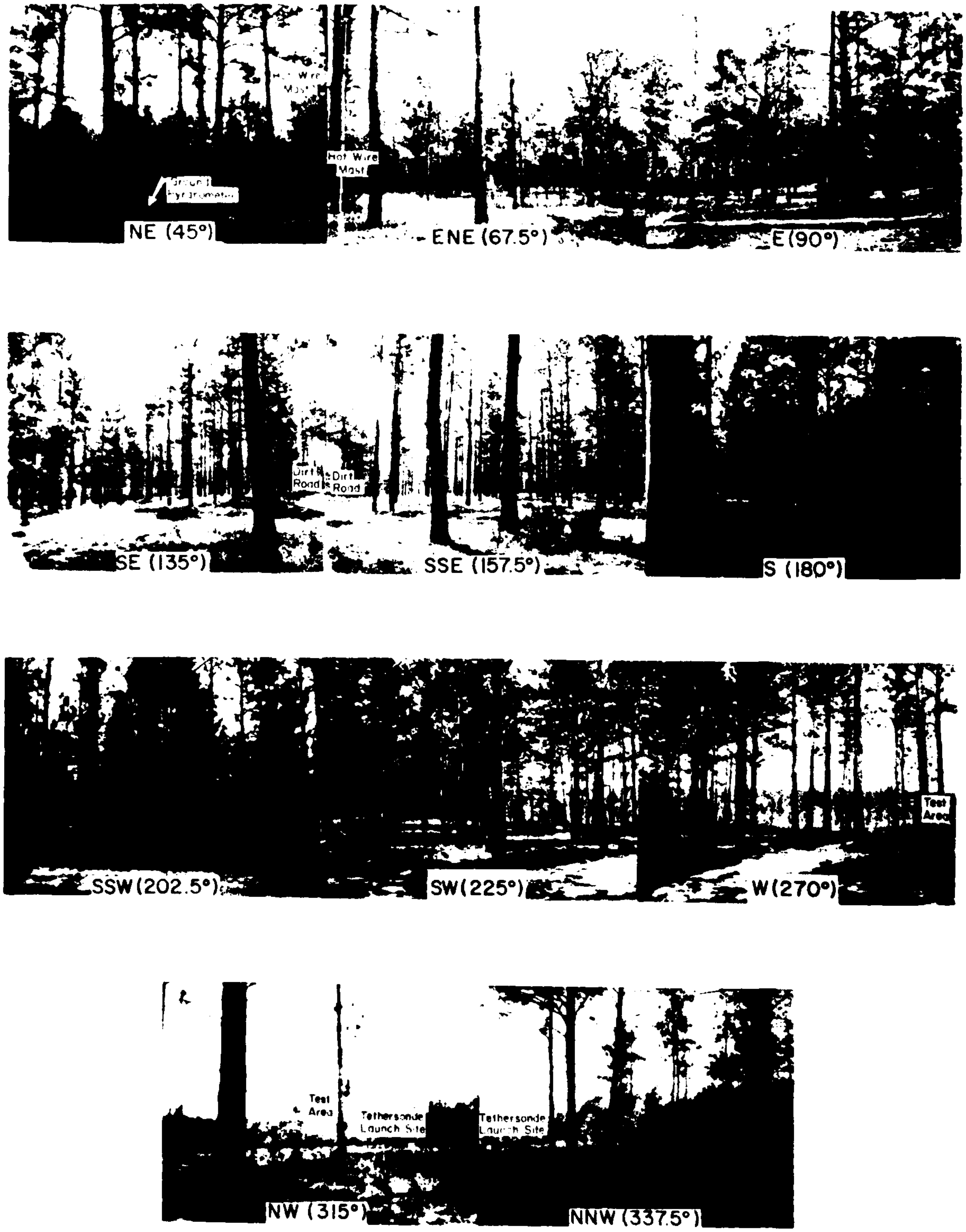


Fig. 5 Panoramic view of the meteorological tower site.

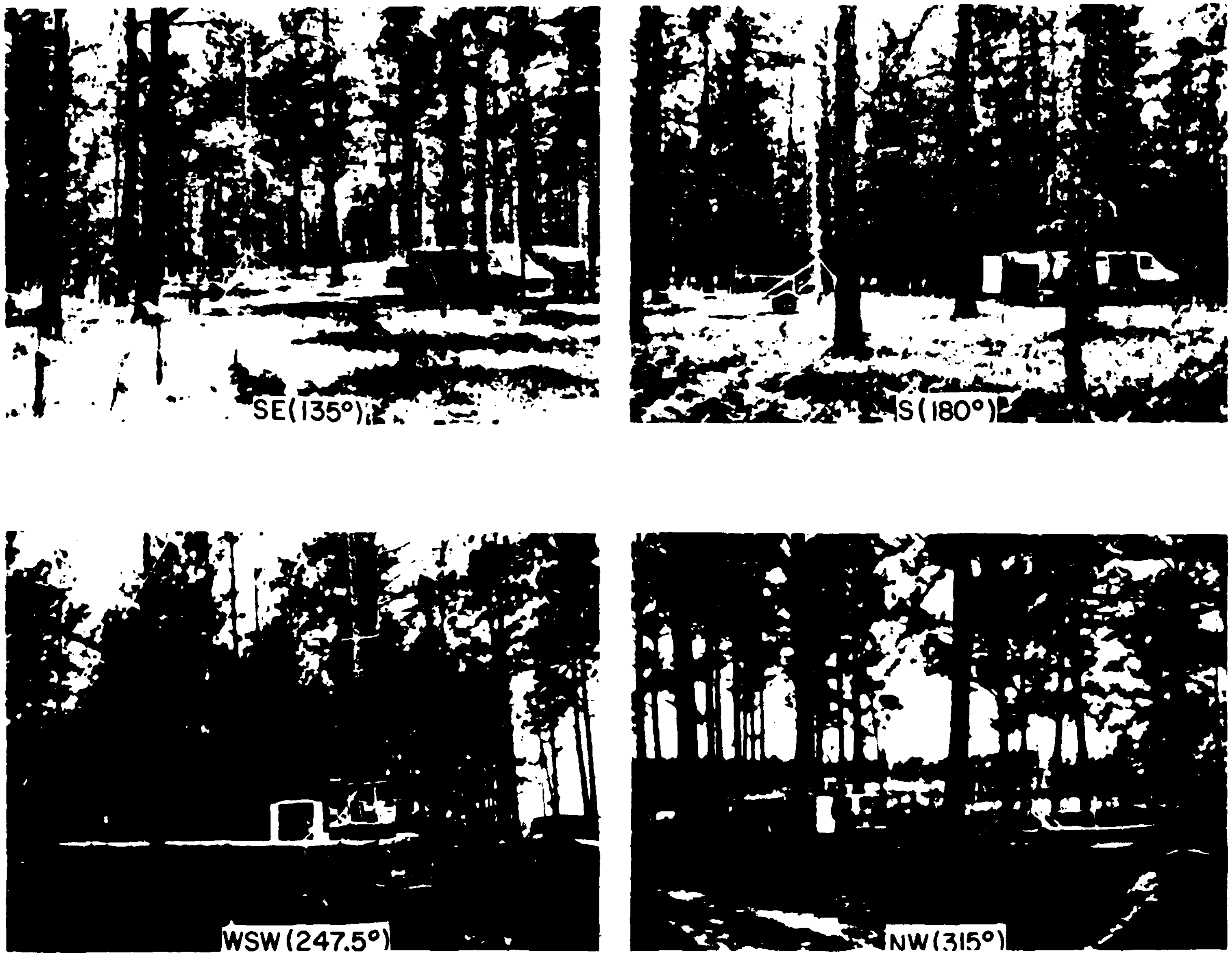


Fig. 6 Meteorological tower site viewed from four different angles.

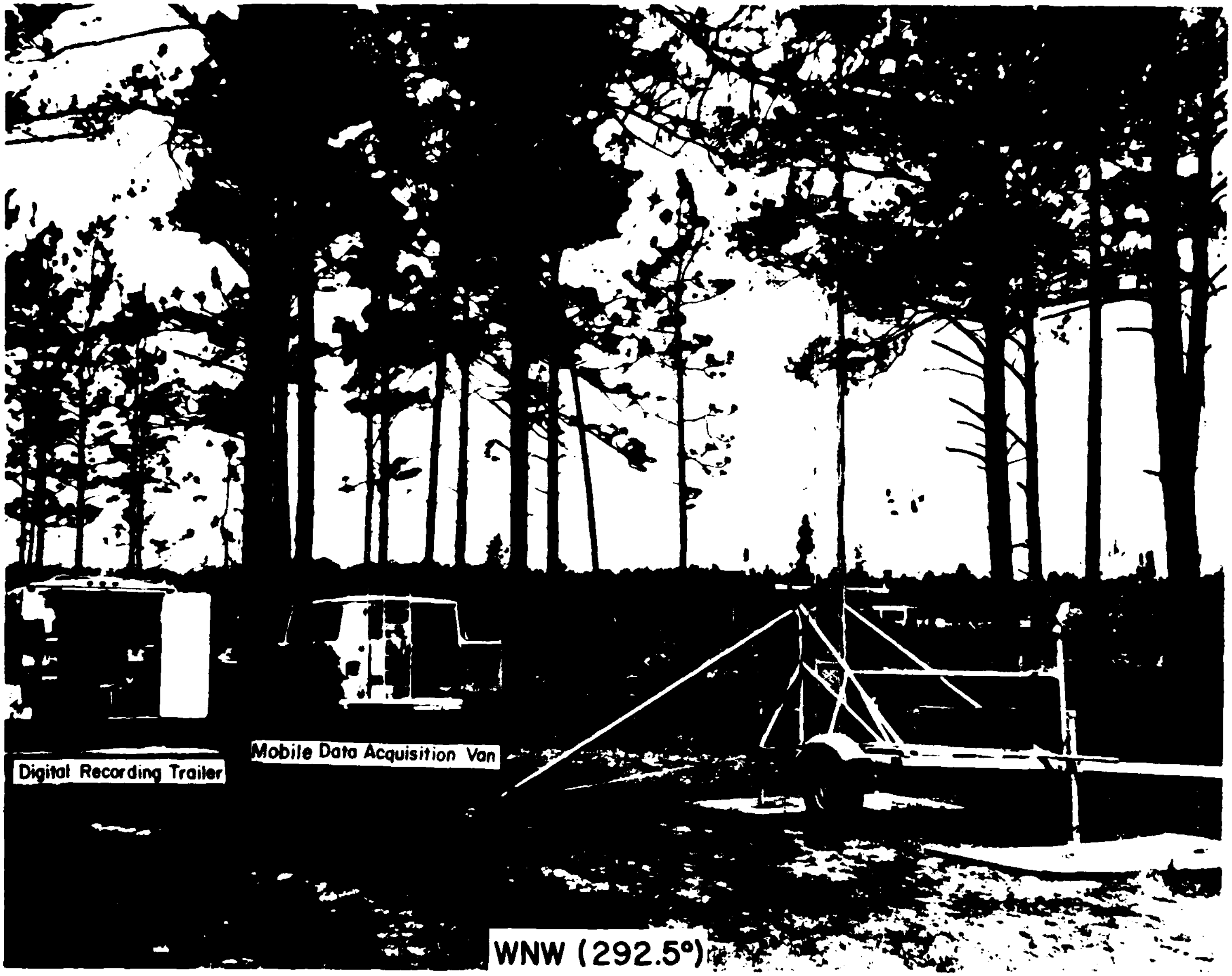


Fig. 7 Close-up view of the meteorological tower site and the two data acquisition units.

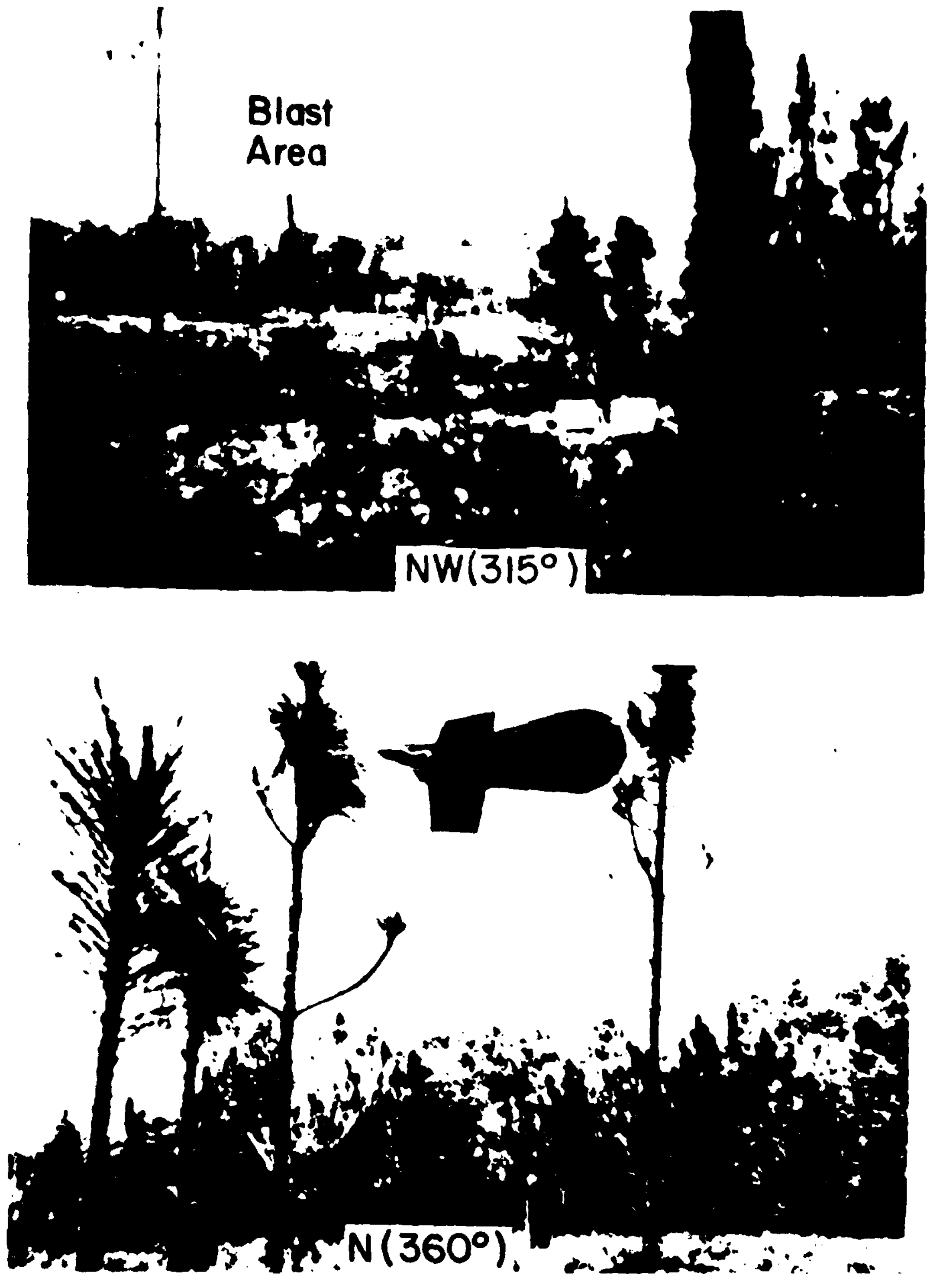


Fig. 8 Two views of the tethersonde balloon site.

Fig. 9 View of the tethersonde balloon and meteorological tower sites.

Fig. 10 View of the meteorological tower.

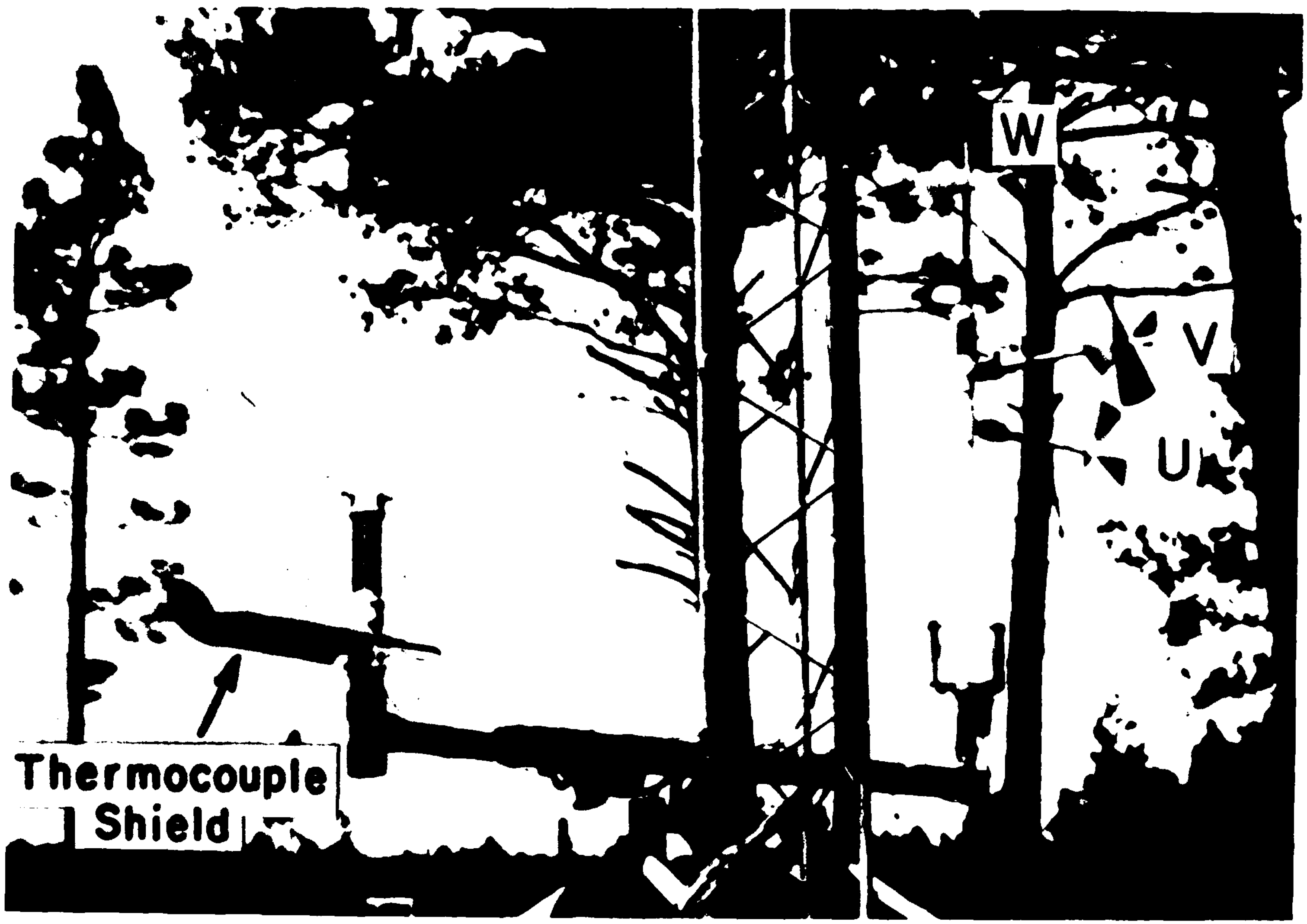


Fig. 11 View of the Gill UVW anemometer and the shielded thermocouple unit mounted on the support arm.

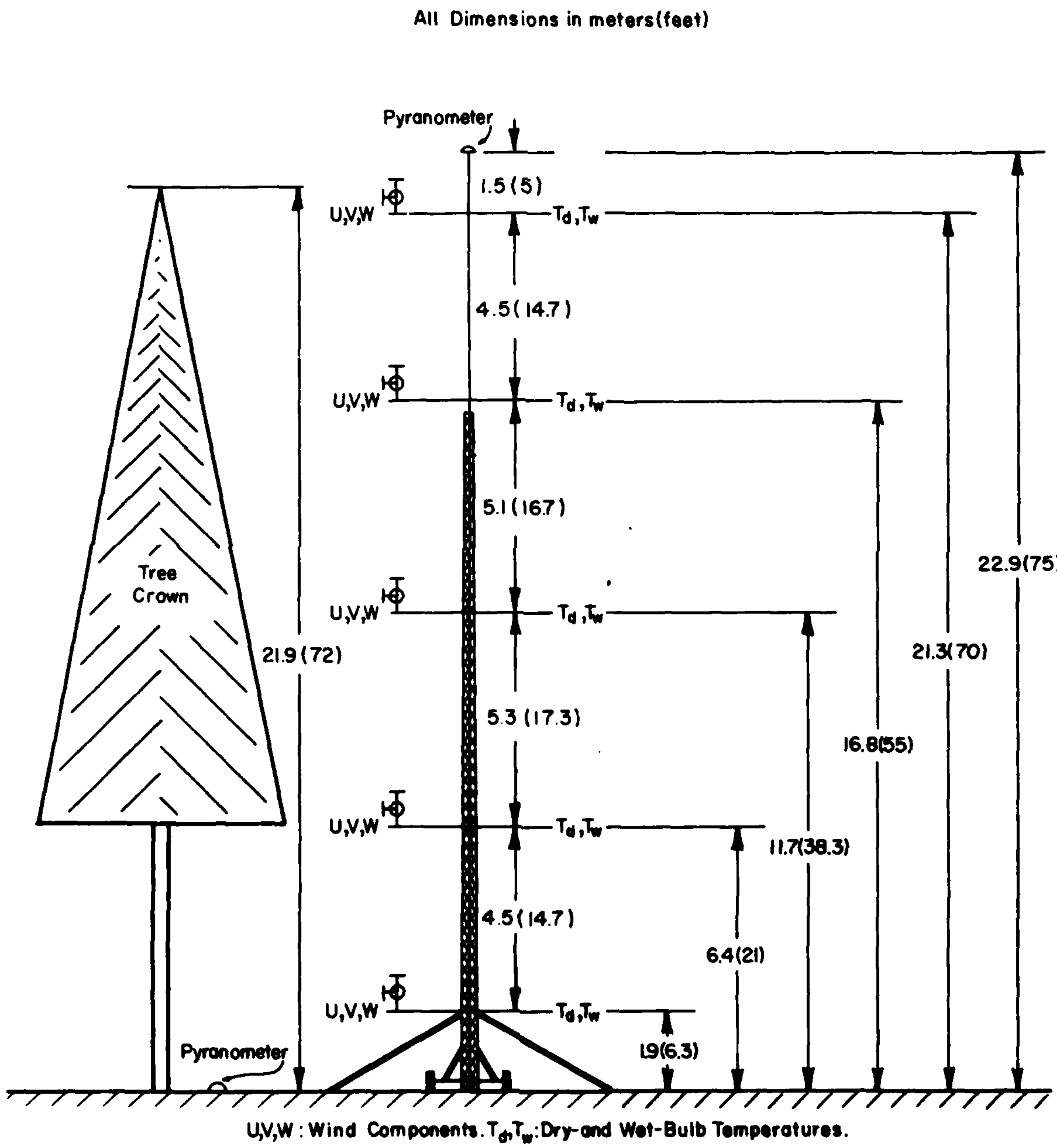


Fig. 12 Instrument level heights in proportion to an average tree.

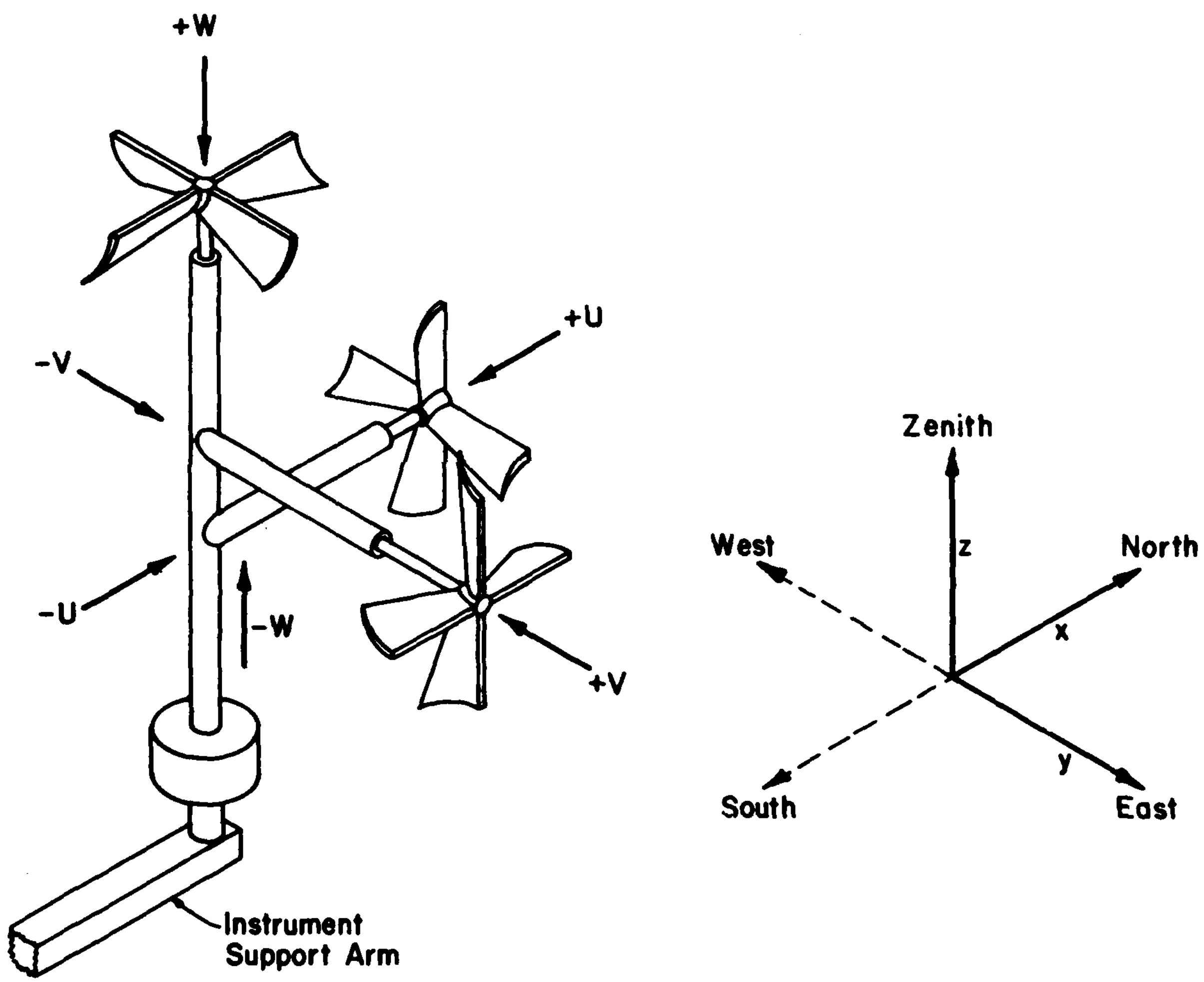


Fig. 13 Gill UVW anemometer sign convention and system of coordinates.

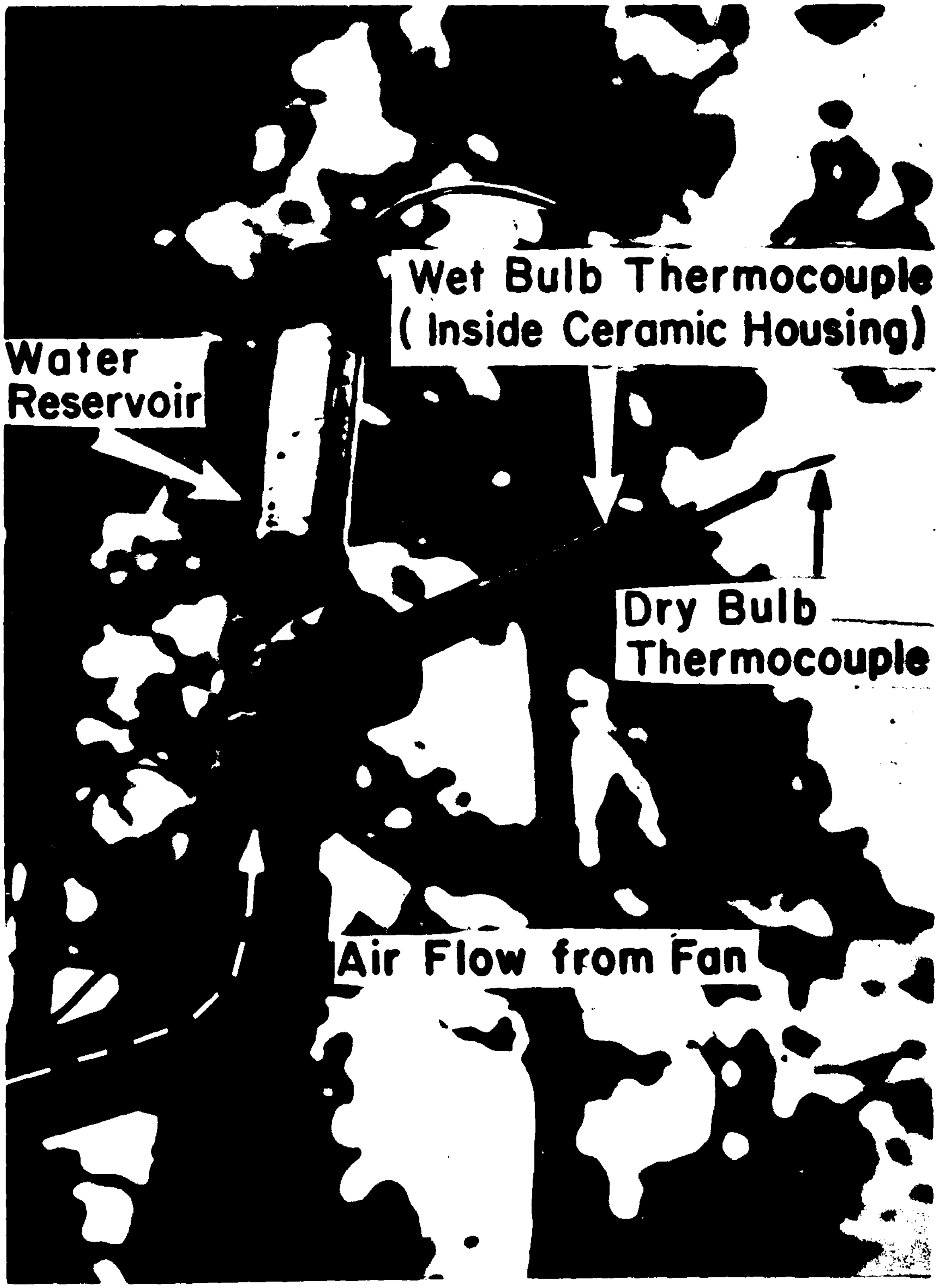
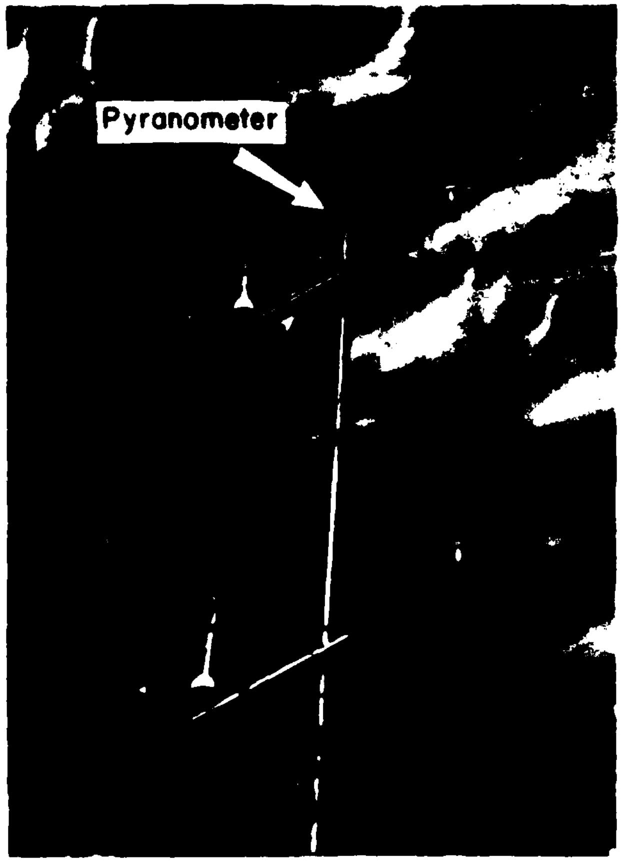


Fig. 14 View of unshielded thermocouple unit.



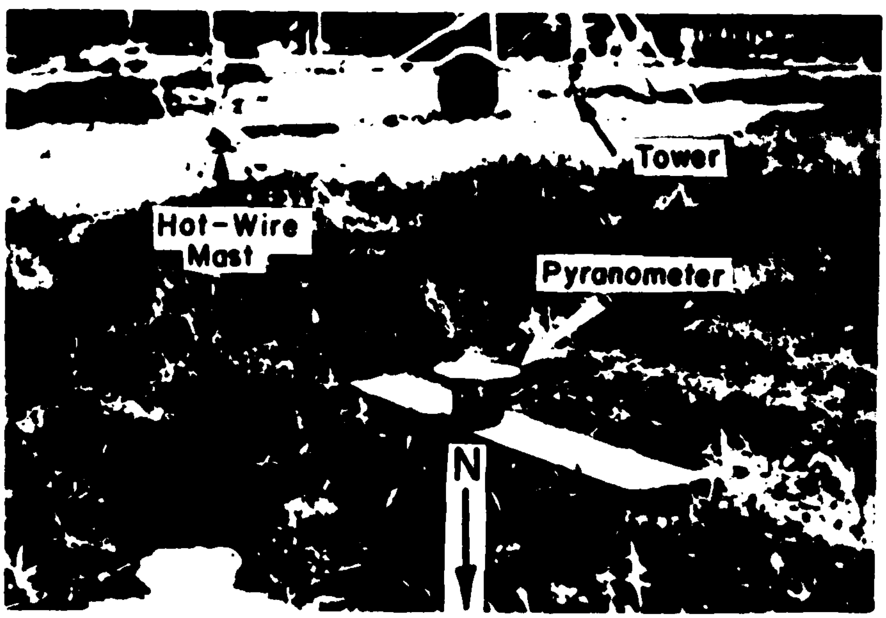


Fig. 15 Views of the tower top and ground-level pyranometers.

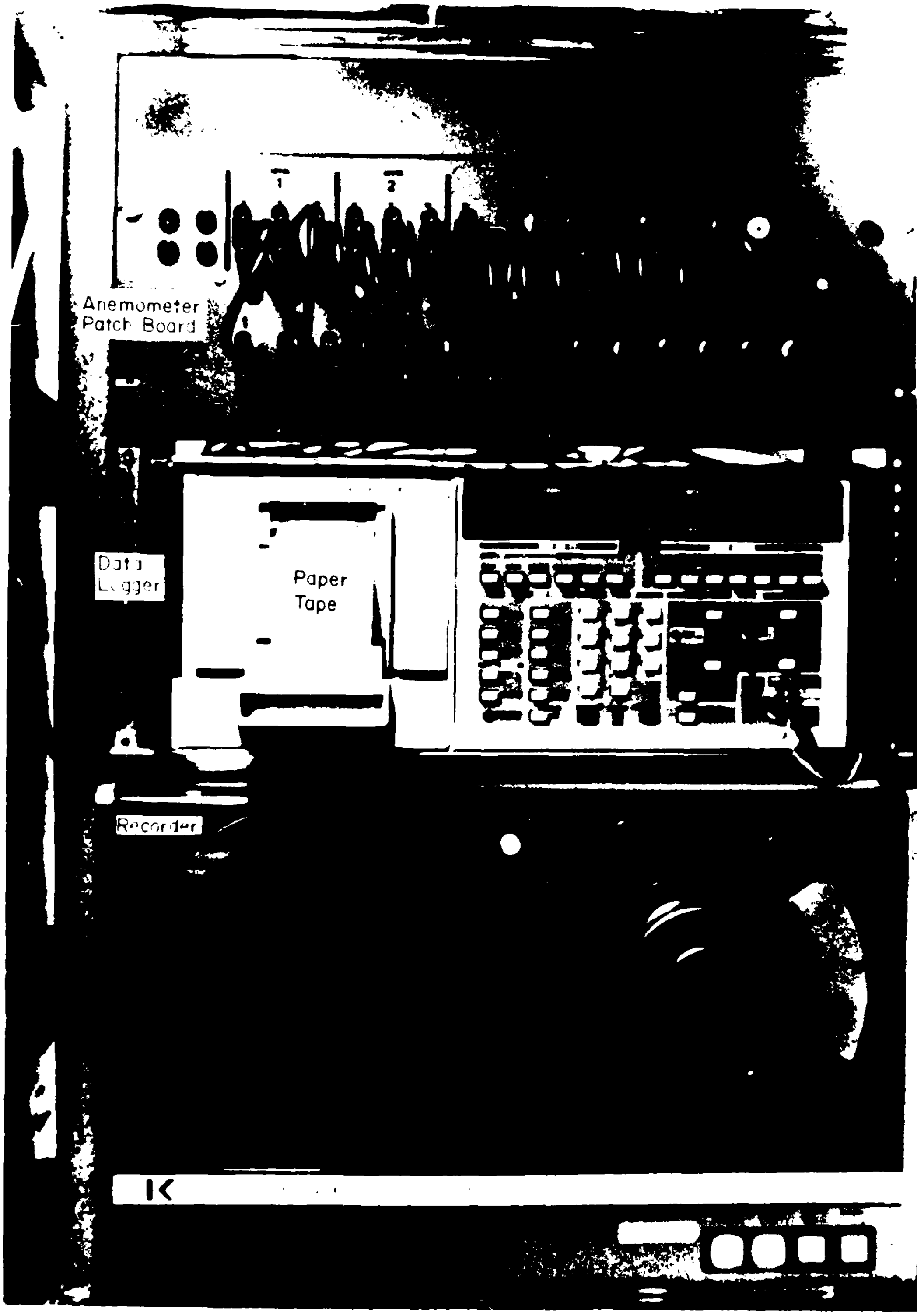


Fig. 16 Digital Data Acquisition System (DDAS).

Fig. 17 Two views of the hot-wire anemometer mast.

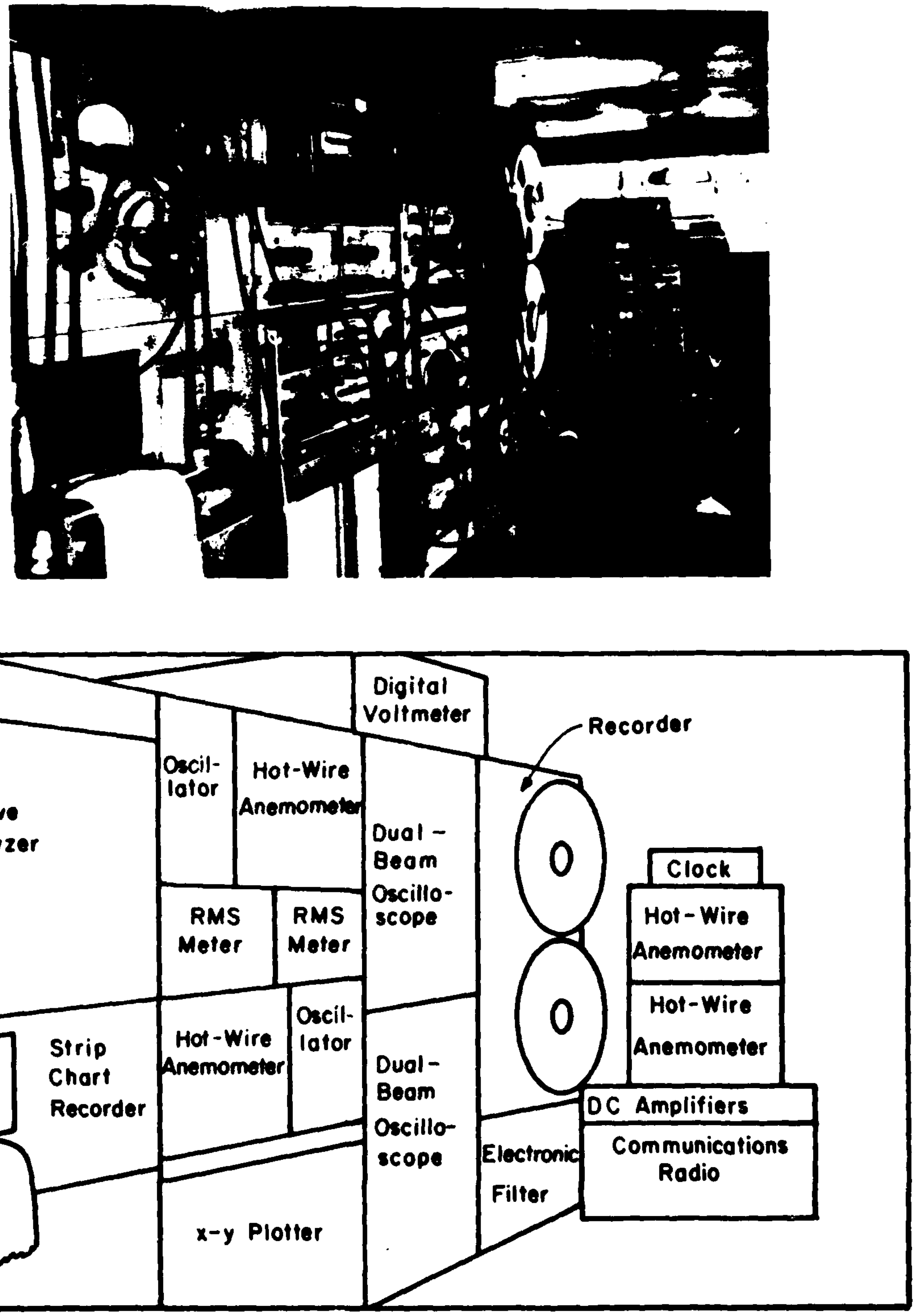


Fig. 18 Analog Data Acquisition System (ADAS).

APPENDIX I.1

DATA LOGGER AND INSTRUMENTATION CALIBRATION

I.1.1 Data logger calibration

A data logger (Fluke Mfg. Co., Model 2240A) consisting of 60 channel divided into six blocks, each of which is made up of 10 channels, was used (see Sect. 4.1). Only three blocks were employed since a total of 27 instruments were monitored, viz., 15 anemometers, 2 pyranometers and 10 thermocouples. A diagram of the channel assignment for each instrument within these three blocks is depicted in Fig. I.1. In addition, the particular output of each instrument and its height on the tower are given in this figure. Note that channels no. 10 in block no. 1 and channels no. 29 and 30 in block no. 3 were shorted since they were not used. The 15 anemometers-viz., 5 Gill UVW anemometers installed at five different height along the tower-were connected to channels no. 1 through 9 in block no. 1 and no. 11 through 16 in block no. 2. Total solar radiation was monitored at canopy top (Q_T) and at ground level (Q_o) by means of two pyranometers connected to channels no. 27 and 28 in block no. 3. This particular arrangement was chosen in order to ensure exactly the same offset for all these 17 channels which was checked against a known voltage source. As a result, the calibration of these 17 channels was identical and it was given by the following linear relationship:

$$y = x + b. \tag{I.1}$$

In this calibration equation, b is the channel offset, x designates the input signal-viz., the signal from any one of the 15 anemometers and the 2 pyranometers-and y stands for the corrected channel output signals. All these three quantities were measured in mV (millivolt).

The 10 thermocouples used to monitor the dry- and wet-bulb temperatures, T_d and T_w, at five levels along the towers were connected to channels no. 17 through 20 in block no. 2 and no. 21 through 26 in block no. 3 as shown in Fig. I.1.1. These 10 channels were calibrated by means of a thermocouple under known conditions so that the output signal was directly converted into degrees centigrade (°C). Different offsets were found for channels no. 17 through 20 and no. 21 through 26. The calibration of these 10 channels was also expressed by a linear relationship

$$T = x + b_T , \tag{I.2}$$

where b_T is the channel offset, x is the input signal from the thermocouples and T stands for the corrected channel output. In the foregoing relationship, the input signal x, the offset b_T and the output signal T are measured directly in degrees centigrade °C as a result of the calibration.

Calibration of all the 27 channels was performed before conducting the measurements and was checked after their completion. A drift in the offsets was found as expected as a result of the continuous use of the data logger. In order to adequately account for the offsets, their value for every measurement day was estimated, as commonly done, by linar interpolation. The offsets for these 27 channels and for every measurement day are tabulated in Table I.1.1 below.

I.1.2 Instrument calibration

A check of the calibration of the 15 anemometers and the 2 pyranometers was conducted in order to verify their specified conversion factors from electrical units into corresponding physical units, i.e.,

TABLE I.1.1. DATA LOGGER CHANNEL OFFSET

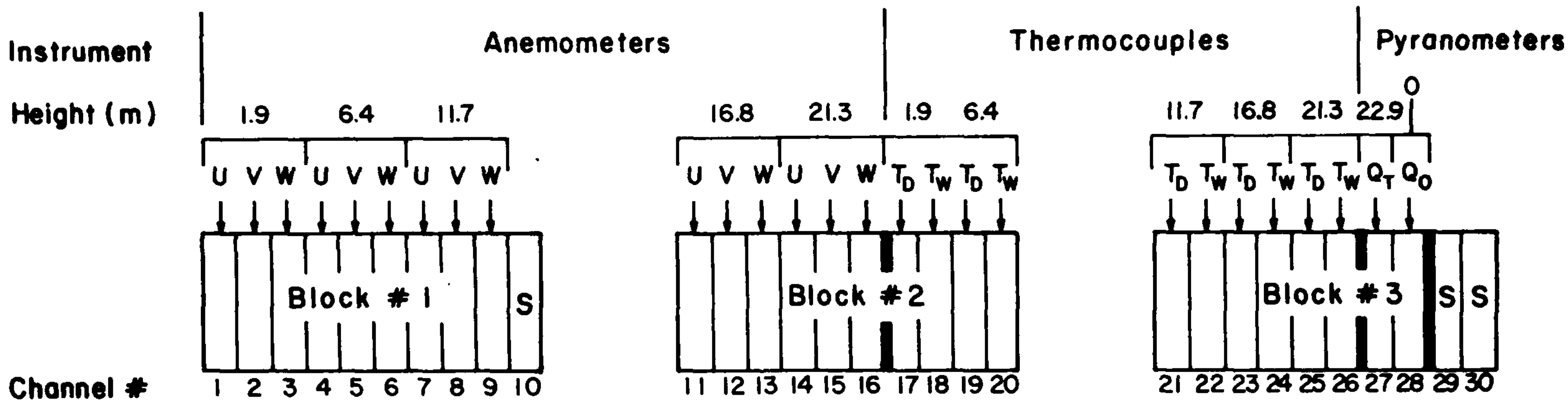
Instrument	Anemometers		Pyranometers	Thermocouples	
Block No.	1	2	3	2	3
Channel No.	1-9	11-16	27-28	17-20	21-26
Date	b (mV)			b_T (°C)	
4/17/80	0.4715			-4.95	0.14
4/18/80	0.4010			-4.95	0.11
4/19/80	0.3300			-4.94	0.09
4/21/80	0.2590			-4.93	0.07
4/22/80	0.1880			-4.92	0.05
4/23/80	0.0460			-4.91	0
4/24/80	0.0250			-4.90	-0.02

from mV into m/s and Ly/min (1 Ly = 4.184 J/cm^2 = 1 cal/cm^2), respectively. All the anemometers, which are identical, have a same conversion factor. The value specified by the manufacturer (R. M. Young Co.) was in excellent agreement with that deduced from a wind-tunnel check. Calibration of the 2 pyranometers was checked by the NOAA Solar Radiation Facility (Boulder, Colorado) after the completion of the measurements. Since the 2 pyranometers were different-viz., Eppley Labs, Inc., Model PSP and Model 15 installed at canopy top and ground level, respectively-their conversion factors were not equal. The conversion factor for the anemometers and the pyranometers are summarized in Table I.1.2 below.

TABLE I.1.2. CONVERSION FACTORS

Instrument	Model	Conversion Factor
Gill UVW Anemometers		1.90439x10 ^{2} ms ^{1}/mV
Eppley Pyranometers	PSP	0.1880 Ly min ^{1}/mV
	15	0.2488 Ly min ^{1}/mV

A flow diagram of the signals showing their offset correction and conversion into physical units is given in Fig. I.1.2.



U, V, W: Wind Components. T_D, T_W : Dry-and Wet-Bulb Temperatures.

Q_T, Q_O : Total Solar Radiation at Tower Top and Ground Level.

S : Shorted Channel.

Fig. I.1.1 Data logger channel assignment for each instrument.

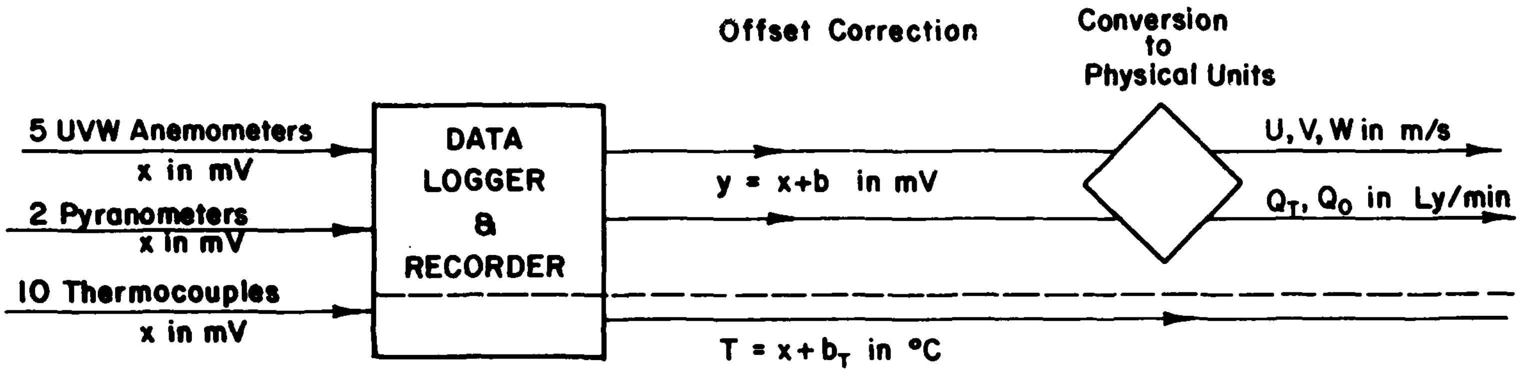


Fig. I.1.2 Flow diagram of the signals showing the offset correction and conversion into physical units.

APPENDIX I.2

NOTATION IN APPENDIXES II-IX AND IN SUPPLEMENTS I-III

In order to facilitate the reading of computer printed out data tables and computer-produced figures presented in Appendixes II through IX and in Supplements I through III, the notation used is documented below.

Term	Quantity
ARITHMETIC MEANS	single sample period mean values
C	degrees centigrade
C/M	degrees centigrade per meter
CST	central standard time
DEG	degrees
DELTA Z	difference in height (m) between two consecutive tower heights
DIR	direction
FT	feet
J	number of data points/one variable in Nth minute of a sample period
K	(1) total number of data points/one variable in first N minutes of a sample period with regard to sequential averages (2) degrees kelvin
LY/MIN	langley per minute
M	meter
MB	millibar
MEAN	mean value
MEAN VELOCITY	mean wind
MIX RATIO	mixing ratio

M/S	meter per second
N(MIN)	minutes per a sample period
NORMALIZED	mean wind and/or rms turbulent wind normalized with respect to the corresponding component at canopy top
NSEQAV	sequential sample mean value over five-minute segment increments
POT TEMP	potential temperature
PRESS	pressure (atmospheric)
RH	relative humidity
RMS	standard deviation of the wind, i.e. turbulent wind
RMS VELOCITY	as above, in the figures
STDV	standard deviation
TEMP	temperature
U,V,W	the three orthogonal components of the mean wind measured by Gill UVW anemometer
Z	height
%	percent
2-D RMS VECTOR	turbulent wind in the horizontal plane

ADDENDUM

Appendixes II through IX, in which the data tables and the figures are presented, were submitted under separate cover on 15 December 1980 and 15 January 1981 because of their large volume. Herein, the introduction to each one of these appendixes is included for the sake of supplying a picture of their contents.

METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX II

PRE- AND POST-BLAST RESULTS: DATA TABLES

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15 December 1980

In this appendix, the results are presented in a tabular form for each pre- and post-blast test according to the blast test sequence outlined below. Similar meteorological data summarized in twenty-one tables are given for each case. A list of the tables, where cross-reference is made to the corresponding figures given in Appendix III, is incorporated.

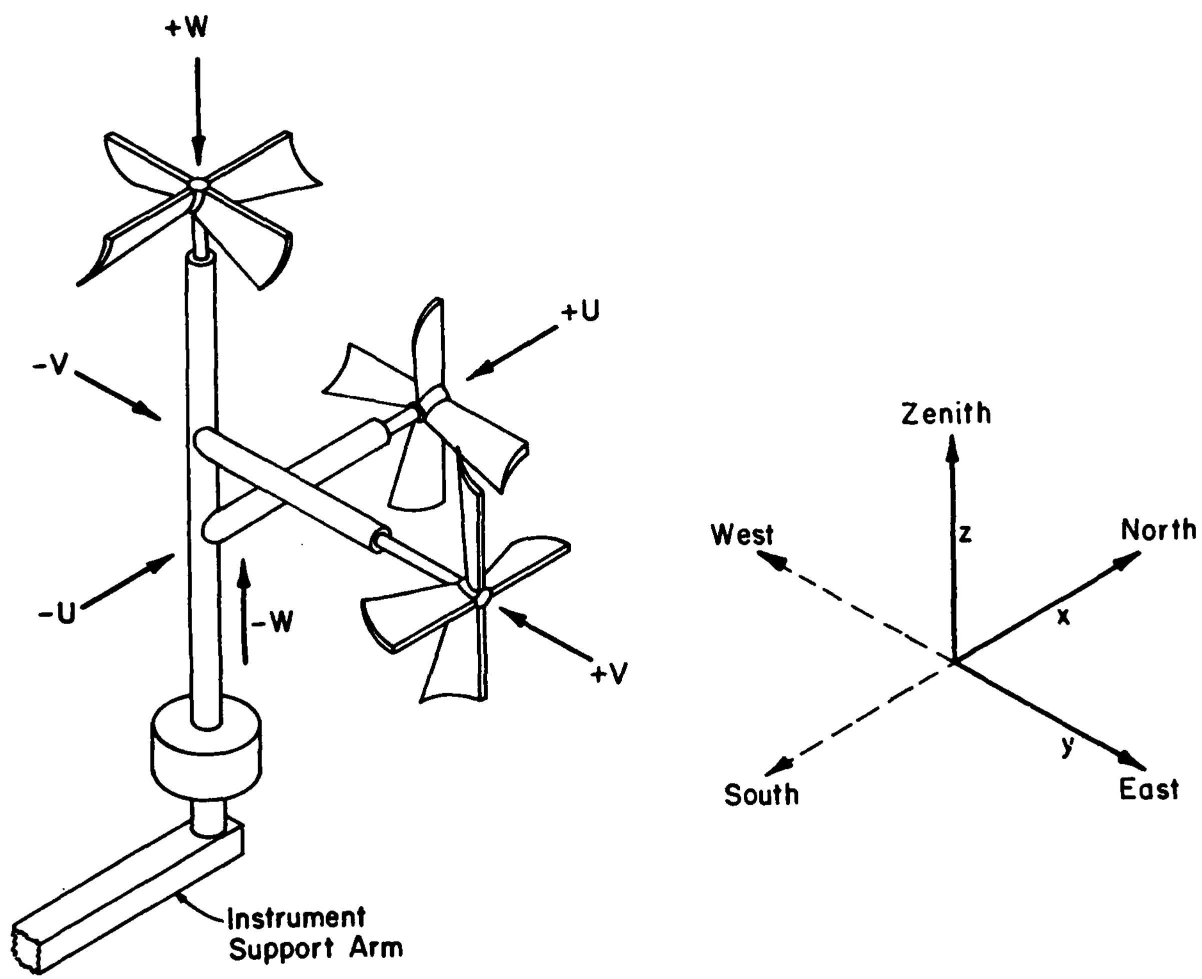
BLAST TEST SEQUENCE

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/17/80	12:39	1-A4-BB	12:09 - 12:39	30
		1-A4-AB	12:39 - 13:05	26
4/18/80	09:08	2-D4-BB	09:03 - 09:07	4
		2-D4-AB	09:08 - 09:30	22
	09:53	3-A5-BB	09:30 - 09:53	23
		3-A5-AB	09:53 - 10:13	20
	10:34	4-A6-BB	10:13 - 10:34	21
		4-A6-AB	10:34 - 10:55	21
	11:16	5-A8-BB	10:55 - 11:16	21
		5-A8-AB	11:16 - 11:39	23
	12:03	6-C7-BB	11:39 - 12:03	24
		6-C7-AB	12:03 - 12:33	30
	13:32	7-D5-BB	13:02 - 13:32	30
		7-D5-AB	13:32 - 13:53	21
	14:13	8-D6-BB	13:53 - 14:13	20
		8-D6-AB	14:13 - 14:32	19
	14:51	9-C5-BB	14:32 - 14:51	19
		9-C5-AB	14:51 - 15:21	30
4/19/80	11:50	10-C4-BB	11:33 - 11:50	17
		10-C4-AB	11:50 - 12:08	18
	12:26	11-B4-BB	12:08 - 12:26	18
		11-B4-AB	12:26 - 12:56	30
	13:27	12-B6-BB	12:57 - 13:27	29
		12-B6-AB	13:27 - 13:51	24
	14:15	13-B7-BB	13:51 - 14:15	24
		13-B7-AB	14:15 - 14:38	23
	15:01	14-D9-BB	14:38 - 15:01	23
		14-D9-AB	15:01 - 15:19	18
4/21/80	13:12	15-C6-BB	12:42 - 13:12	30
		15-C6-AB	13:12 - 13:34	22
	13:56	16-A7-BB	13:34 - 13:56	22
		16-A7-AB	13:56 - 14:26	30
	15:00	17-B8-BB	14:30 - 15:00	30
		17-B8-AB	15:00 - 15:18	18
	15:36	18-E7-BB	15:18 - 15:36	18
		18-E7-AB	15:36 - 15:55	19
	16:15	19-E8-BB	15:55 - 16:15	20
		19-E8-AB	16:15 - 16:37	22
	16:58	20-E5-BB	16:37 - 16:58	21
		20-E5-AB	16:58 - 17:15	17

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/22/80	12:12	21-B5-BB	11:42 - 12:12	30
		21-B5-AB	12:12 - 12:42	30
	14:03	22-D8-BB	13:33 - 14:03	30
		22-D8-AB	14:03 - 14:33	30
	15:24	23-E6-BB	14:54 - 15:24	30
		23-E6-AB	15:24 - 15:49	25
	16:14	24-A9-BB	15:49 - 16:14	25
		24-A9-AB	16:14 - 16:44	30
4/23/80	09:37	25-B9-BB	09:10 - 09:37	27
		25-B9-AB	09:37 - 09:56	19
	10:15	26-C8-BB	09:56 - 10:15	19
		26-C8-AB	10:15 - 10:33	18
	10:52	27-C9-BB	10:33 - 10:52	19
		27-C9-AB	10:52 - 11:22	30

Table #	Content	Fig. # (see Appendix III)
1	North/South U, East/West V, Downward/Upward W, mean wind--sample arithmetic mean	
2	North/South U, East/West V, Downward/Upward W, normalized mean wind--sample arithmetic mean	
3	North/South U, East/West V, Downward/Upward W, turbulent wind RMS value (wind standard deviation)	
4	North/South U, East/West V, Downward/Upward W, normalized turbulent wind RMS value (wind standard deviation)	
5	North/South U, East/West V, Downward/Upward W, turbulence intensities	
6	Turbulent wind RMS value (speed & direction) in the horizontal plane	14
7	North/South U, East/West V, Downward/Upward W--one-minute average	1,3,5
8	North/South U, East/West V, Downward/Upward W--sequential average	2,4,6
9	North/South U, East/West V, Downward/Upward W--sequential average over varying sample size N	
10	Mean and normalized mean wind (speed & direction) in the horizontal plane	11,12, 13,15
11	Mean and normalized mean instantaneous wind (speed & direction) in the horizontal plane	16
12	Mean and normalized mean wind (speed & direction) in space	
13	Mean wind in horizontal plane (speed & direction)--one-minute average	7,9
14	Mean wind in horizontal plane (speed & direction)--sequential average	8,10
15	Vertical profile of the dry and wet bulb mean temperature	21,22
	Vertical profile of the potential temperature	
	Vertical profile of the dew point and relative humidity	23,24
	Vertical profile of the dry and wet bulb temperature standard deviation	
16	Vertical gradient of the dry bulb and potential temperature	
17	Total solar radiation--sample mean and standard deviation	
18	Dry and wet bulb temperature--one-minute average	17,18
19	Dew point temperature and relative humidity--one-minute average	19,20
20	Total solar radiation--one-minute and sequential average	25
21	Number and time of records in each minute of data	

The sign convention for the Gill UVW anemometer and the system of coordinates used are shown in the following figure.



Gill UVW anemometer sign convention and system of coordinates

METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX III

PRE- AND POST-BLAST RESULTS: FIGURES

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15 December 1980

In this appendix, the figures in which the results are displayed are given. This appendix consists of six sections; in each section the pre- and post-blast meteorological data for a single day are shown. Twenty-five figures are presented for each case in the order outlined in the content table given herein.

Section III.1/04-17-1980

In this section the meteorological data for the pre- and post-blast periods for the blast tests conducted on April 17, 1980, are given. The blast time, the test code, the sample period and the number of minutes per sample are tabulated in the table below:

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/17/80	12:39	1-A4-BB	12:09 - 12:39	30
		1-A4-AB	12:39 - 13:05	26

Section III.2/04-18-1980

In this section the meteorological data for the pre- and post-blast periods for the blast tests conducted on April 18, 1980, are given. The blast time, the test code, the sample period and the number of minutes per sample are tabulated in the table below:

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/18/80	09:08	2-D4-BB	09:03 - 09:07	4
		2-D4-AB	09:08 - 09:30	22
	09:53	3-A5-BB	09:30 - 09:53	23
		3-A5-AB	09:53 - 10:13	20
	10:34	4-A6-BB	10:13 - 10:34	21
		4-A6-AB	10:34 - 10:55	21
	11:16	5-A8-BB	10:55 - 11:16	21
		5-A8-AB	11:16 - 11:39	23
	12:03	6-C7-BB	11:39 - 12:03	24
		6-C7-AB	12:03 - 12:33	30
	13:32	7-D5-BB	13:02 - 13:32	30
		7-D5-AB	13:32 - 13:53	21
	14:13	8-D6-BB	13:53 - 14:13	20
		8-D6-AB	14:13 - 14:32	19
	14:51	9-C5-BB	14:32 - 14:51	19
		9-C5-AB	14:51 - 15:21	30

Section III.3/04-19-1980

In this section the meteorological data for the pre- and post-blast periods for the blast tests conducted on April 19, 1980, are given. The blast time, the test code, the sample period and the number of minutes per sample are tabulated in the table below:

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/19/80	11:50	10-C4-BB	11:33 - 11:50	17
		10-C4-AB	11:50 - 12:08	18
	12:26	11-B4-BB	12:08 - 12:26	18
		11-B4-AB	12:26 - 12:56	30
	13:27	12-B6-BB	12:57 - 13:27	29
		12-B6-AB	13:27 - 13:51	24
	14:15	13-B7-BB	13:51 - 14:15	24
		13-B7-AB	14:15 - 14:39	23
	15:01	14-D9-BB	14:38 - 15:01	23
		14-D9-AB	15:01 - 15:19	18

Section III.4/04-21-1980

In this section the meteorological data for the pre- and post-blast periods for the blast tests conducted on April 21, 1980, are given. The blast time, the test code, the sample period and the number of minutes per sample are tabulated in the table below:

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/21/80	13:12	15-C6-BB	12:42 - 13:12	30
		15-C6-AB	13:12 - 13:34	22
	13:56	16-A7-BB	13:34 - 13:56	22
		16-A7-AB	13:56 - 14:26	30
	15:00	17-B8-BB	14:30 - 15:00	30
		17-B8-AB	15:00 - 15:18	18
	15:36	18-E7-BB	15:18 - 15:36	18
		18-E7-AB	15:36 - 15:55	19
	16:15	19-E8-BB	15:55 - 16:15	20
		19-E8-AB	16:15 - 16:37	22
	16:58	20-E5-BB	16:37 - 16:58	21
		20-E5-AB	16:58 - 17:15	17

Section III.5/04-22-1980

In this section the meteorological data for the pre- and post-blast periods for the blast tests conducted on April 22, 1980, are given. The blast time, the test code, the sample period and the number of minutes per sample are tabulated in the table below:

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/22/80	12:12	21-B5-BB	11:42 - 12:12	30
		21-B5-AB	12:12 - 12:42	30
	14:03	22-D8-BB	13:33 - 14:03	30
		22-D8-AB	14:03 - 14:33	30
	15:24	23-E6-BB	14:54 - 15:24	30
		23-E6-AB	15:24 - 15:49	25
	16:14	24-A9-BB	15:49 - 16:14	25
		24-A9-AB	16:14 - 16:44	30

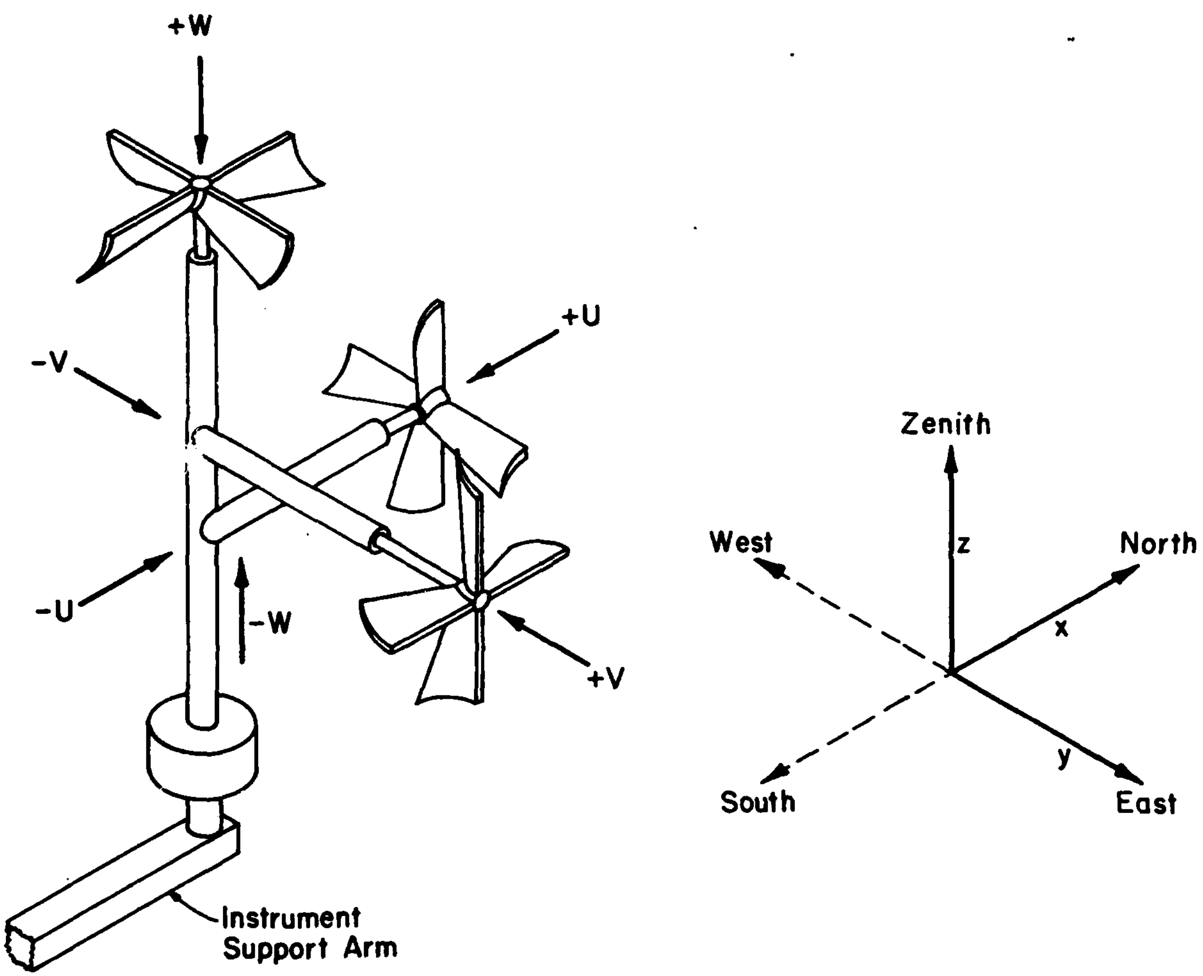
Section III.6/04-23-1980

In this section the meteorological data for the pre- and post-blast periods for the blast tests conducted on April 23, 1980, are given. The blast time, the test code, the sample period and the number of minutes per sample are tabulated in the table below:

DATE	BLAST TIME (CST)	TEST CODE	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/23/80	09:37	25-B9-BB	09:10 - 09:37	27
		25-B9-AB	09:37 - 09:56	19
	10:15	26-C8-BB	09:56 - 10:15	19
		26-C8-AB	10:15 - 10:33	18
	10:52	27-C9-BB	10:33 - 10:52	19
		27-C9-AB	10:52 - 11:22	30

Fig. #	Content
1	North/South wind U anemometer one-minute average
2	North/South wind U anemometer sequential average
3	East/West wind V anemometer one-minute average
4	East/West wind V anemometer sequential average
5	Downward/Upward wind W anemometer one-minute average
6	Downward/Upward wind W anemometer sequential average
7	Wind speed in the horizontal plane one-minute average
8	Wind speed in the horizontal plane sequential average
9	Wind direction in the horizontal plane one-minute average
10	Wind direction in the horizontal plane sequential average
11	Vertical profile of mean wind speed in the horizontal plane
12	Vertical profile of normalized mean wind speed in the horizontal plane
13	Vertical profile of mean wind direction in the horizontal plane
14	Vertical profile of RMS wind speed in the horizontal plane
15	Wind rose of horizontal mean wind-arithmetic average
16	Wind rose of horizontal mean wind-arithmetic average of instantaneous wind
17	Dry bulb temperature one-minute average
18	Wet bulb temperature one-minute average
19	Dew point temperature one-minute average
20	Relative humidity one-minute average
21	Vertical profile of mean dry bulb temperature
22	Vertical profile of mean wet bulb temperature
23	Vertical profile of mean dew point temperature
24	Vertical profile of mean relative humidity
25	Total solar radiation one-minute average

The sign convention for the Gill UVW anemometer and the system of coordinates used are shown in the following figure.



Gill UVW anemometer sign convention and system of coordinates

METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX IV

TETHERSONDE BALLOON SURVEYS: DATA TABLES

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Fort Collins, Colorado 80523
15 January 1981

The results of the sounding performed with the tethersonde balloon are tabulated in the tables given in this appendix. They are summarized according to the blast test sequence outlined below and are indexed accordingly. A list of the data presented in each table, along with cross-references to the corresponding figures included in Appendix V, is provided.

TETHERSONDE BALLOON SURVEY SEQUENCE

DATE	BLAST TIME (CST)	TEST CODE & FIGURE INDEX	TETHERSONDE BALLOON SAMPLE PERIOD (CST)	MAXIMUM ALTITUDE (m)
04/18/80	14:51	9-C5-AB	15:44 - 15:48	71
04/19/80	12:26	11-B4-AB	12:38 - 12:49	65
	15:01	14-D9-BB	14:41 - 14:48	89
04/21/80	13:12	15-C6-BB	09:23 - 09:36	165
	13:12	15-C6-AB	13:20 - 13:29	155
	16:15	19-E8-BB	16:01 - 16:11	159
04/22/80	14:03	22-D8-BB	13:48 - 13:53	136
	16:14	24-A9-AB	16:29 - 16:39	193
04/23/80	09:37	25-B9-BB	08:37 - 08:59	175
	10:52	27-C9-AB	11:23 - 11:37	179

DATA PRESENTED IN EACH TABLE

	Fig. # (see Appendix V)
Sample time (CST)	given in all figures
Height	
Atmospheric pressure	1
Mean temperature	5
Relative humidity	7
Mixing ratio	8
Mean wind speed	2,4
Mean wind direction	3,4
Potential temperature	6

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METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX V

TETHERSONDE BALLOON SURVEYS: FIGURES

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15 January 1981

All the results of the tethersonde balloon surveys tabulated in Appendix IV are displayed in the figures given in this appendix. The results for each sample period, according to the sequence outlined in the table below, are portrayed in eight figures. In each one of these eight figures, the data for a different meteorological parameter are shown. The order in which these figures are presented is outlined in the list of figures given herein. Note that the wind rose is shown in several figures for the sake of clarity, so that no more than ten wind vectors are included in each figure.

TETHERSONDE BALLOON SURVEY SEQUENCE

DATE	BLAST TIME (CST)	TEST CODE & FIGURE INDEX	TETHERSONDE BALLOON SAMPLE PERIOD (CST)	MAXIMUM ALTITUDE (m)
04/18/80	14:51	9-C5-AB	15:44 - 15:48	71
04/19/80	12:26	11-B4-AB	12:38 - 12:49	65
	15:01	14-D9-BB	14:41 - 14:48	89
04/21/80	13:12	15-C6-BB	09:23 - 09:36	165
	13:12	15-C6-AB	13:20 - 13:29	155
	16:15	19-E8-BB	16:01 - 16:11	159
04/22/80	14:03	22-D8-BB	13:48 - 13:53	136
	16:14	24-A9-AB	16:29 - 16:39	193
04/23/80	09:37	25-B9-BB	08:37 - 08:59	175
	10:52	27-C9-AB	11:23 - 11:37	179

Fig. # List of Figures

METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX VI

BACKGROUND METEOROLOGICAL DATA: DATA TABLES

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15 January 1981

The results during periods with no blasts-i.e., background meteorological data, called BMD herein for convenience-are tabulated in the tables given in this appendix. The sample periods are presented according to the sequence shown in the table below. Similar meteorological data summarized in twenty-one tables are given for each case. A list of the tables, where cross-reference is made to the corresponding figures given in Appendix VII, is incorporated.

BACKGROUND METEOROLOGICAL DATA

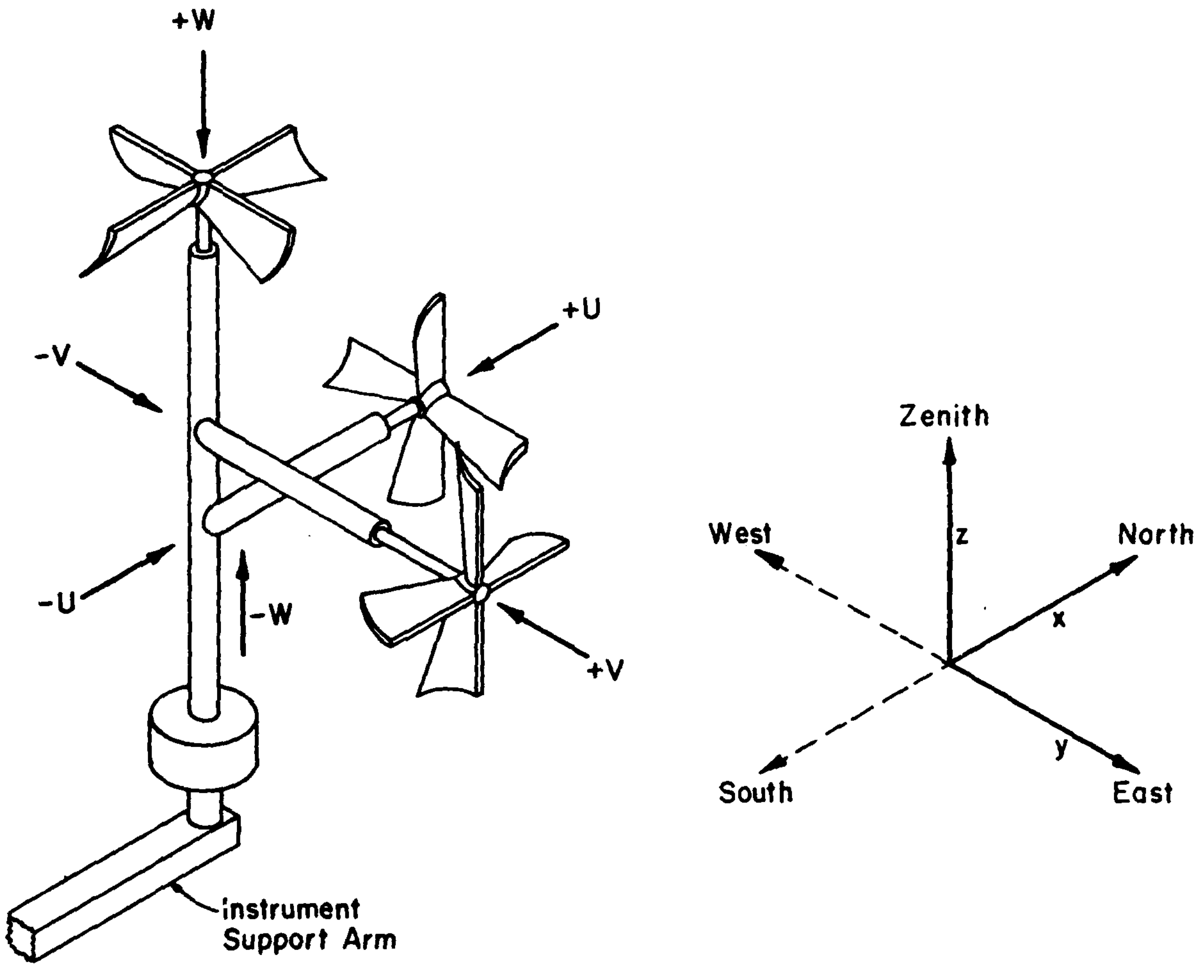
TEST SEQUENCE

DATE	TEST CODE TABLE & FIGURE INDEX	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/22/80	BMD-22-1	18:00 - 18:30	30
	BMD-22-2	20:00 - 20:30	30
	BMD-22-3	22:00 - 22:30	30
4/23/80	BMD-23-1	01:00 - 01:30	30
	BMD-23-2	04:00 - 04:30	30
	BMD-23-3	06:00 - 06:30	30
	BMD-23-4	08:00 - 08:30	30
4/24/80	BMD-24-1	11:00 - 11:30	30
	BMD-24-2	12:00 - 12:30	30
	BMD-24-3	13:00 - 13:30	30
	BMD-24-4	14:00 - 14:30	30
	BMD-24-5	15:00 - 15:30	30
	BMD-24-6	16:00 - 16:30	30

The last digit in the test code indicates the test number.

Table #	Content	Fig. # (see Appendix VII)
1	North/South U, East/West V, Downward/Upward W, mean wind--sample arithmetic mean	
2	North/South U, East/West V, Downward/Upward W, normalized mean wind--sample arithmetic mean	
3	North/South U, East/West V, Downward/Upward W, turbulent wind RMS value (wind standard deviation)	
4	North/South U, East/West V, Downward/Upward W, normalized turbulent wind RMS value (wind standard deviation)	
5	North/South U, East/West V, Downward/Upward W, turbulence intensities	
6	Turbulent wind RMS value (speed & direction) in the horizontal plane	14
7	North/South U, East/West V, Downward/Upward W--one-minute average	1,3,5
8	North/South U, East/West V, Downward/Upward W--sequential average	2,4,6
9	North/South U, East/West V, Downward/Upward W--sequential average over varying sample size N	
10	Mean and normalized mean wind (speed & direction) in the horizontal plane	11,12, 13,15
11	Mean and normalized mean instantaneous wind (speed & direction) in the horizontal plane	16
12	Mean and normalized mean wind (speed & direction) in space	
13	Mean wind in horizontal plane (speed & direction)--one-minute average	7,9
14	Mean wind in horizontal plane (speed & direction)--sequential average	8,10
15	Vertical profile of the dry and wet bulb mean temperature	21,22
	Vertical profile of the potential temperature	
	Vertical profile of the dew point and relative humidity	23,24
	Vertical profile of the dry and wet bulb temperature standard deviation	
16	Vertical gradient of the dry bulb and potential temperature	
17	Total solar radiation--sample mean and standard deviation	
18	Dry and wet bulb temperature--one-minute average	17,18
19	Dew point temperature and relative humidity--one-minute average	19,20
20	Total solar radiation--one-minute and sequential average	25
21	Number and time of records in each minute of data	

The sign convention for the Gill UVW anemometer and the system of coordinates used are shown in the following figure.



Gill UVW anemometer sign convention and system of coordinates

METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX VII

BACKGROUND METEOROLOGICAL DATA: FIGURES

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15 January 1981

All the results on the background meteorological data which are tabulated in Appendix VI are displayed in the figures given in this appendix. The results for each sample period, according to the sequence outlined in the table below, are portrayed in twenty-five figures. The order in which these figures are presented is outlined in the list of figures given herein.

BACKGROUND METEOROLOGICAL DATA

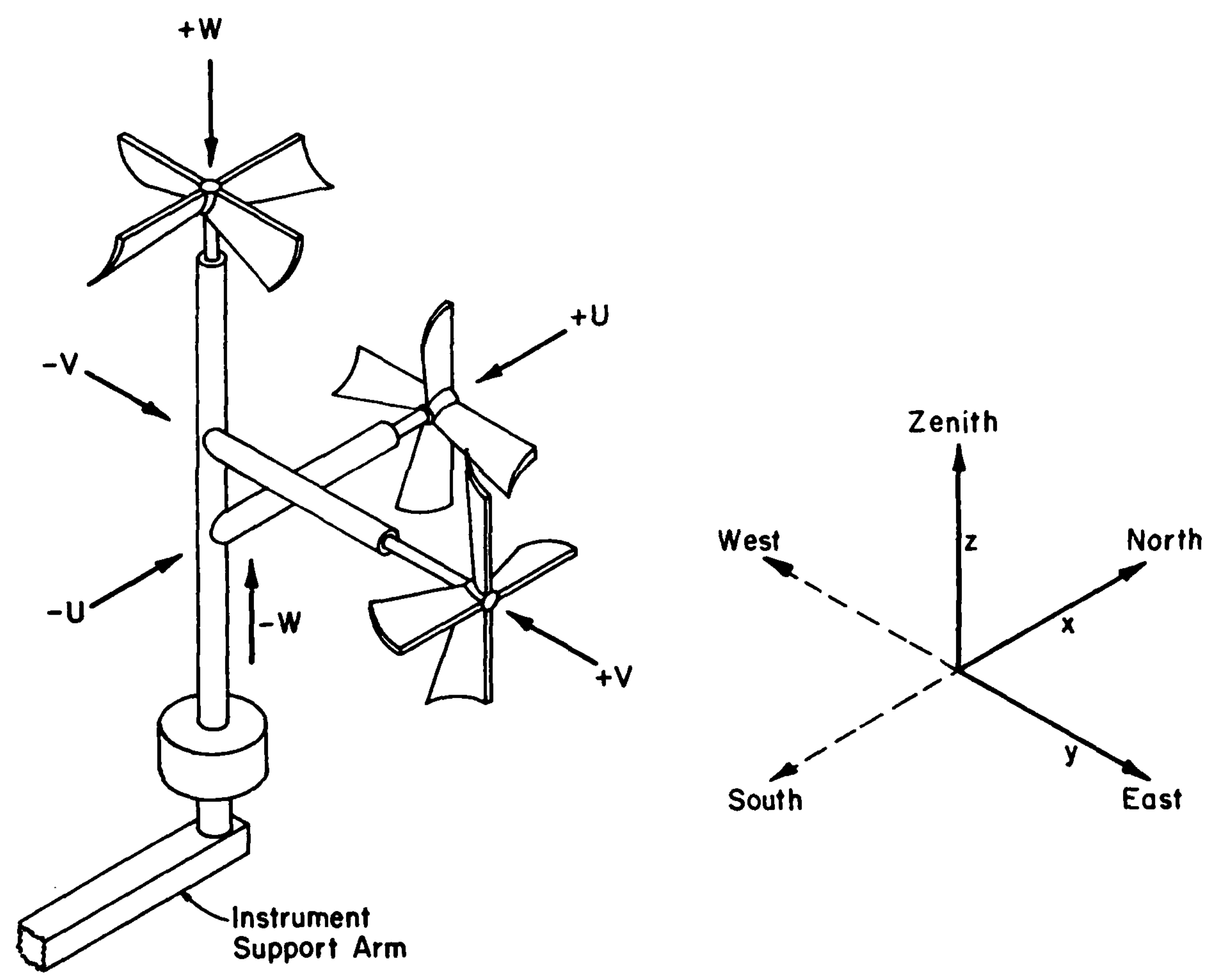
TEST SEQUENCE

DATE	TEST CODE TABLE & FIGURE INDEX	SAMPLE PERIOD (CST)	MINUTES PER SAMPLE
4/22/80	BMD-22-1	18:00 - 18:30	30
	BMD-22-2	20:00 - 20:30	30
	BMD-22-3	22:00 - 22:30	30
4/23/80	BMD-23-1	01:00 - 01:30	30
	BMD-23-2	04:00 - 04:30	30
	BMD-23-3	06:00 - 06:30	30
	BMD-23-4	08:00 - 08:30	30
4/24/80	BMD-24-1	11:00 - 11:30	30
	BMD-24-2	12:00 - 12:30	30
	BMD-24-3	13:00 - 13:30	30
	BMD-24-4	14:00 - 14:30	30
	BMD-24-5	15:00 - 15:30	30
	BMD-24-6	16:00 - 16:30	30

The last digit in the test code indicates the test number.

Fig. #	Content
1	North/South wind U anemometer one-minute average
2	North/South wind U anemometer sequential average
3	East/West wind V anemometer one-minute average
4	East/West wind V anemometer sequential average
5	Downward/Upward wind W anemometer one-minute average
6	Downward/Upward wind W anemometer sequential average
7	Wind speed in the horizontal plane one-minute average
8	Wind speed in the horizontal plane sequential average
9	Wind direction in the horizontal plane one-minute average
10	Wind direction in the horizontal plane sequential average
11	Vertical profile of mean wind speed in the horizontal plane
12	Vertical profile of normalized mean wind speed in the horizontal plane
13	Vertical profile of mean wind direction in the horizontal plane
14	Vertical profile of RMS wind speed in the horizontal plane
15	Wind rose of horizontal mean wind-arithmetic average
16	Wind rose of horizontal mean wind-arithmetic average of instantaneous wind
17	Dry bulb temperature one-minute average
18	Wet bulb temperature one-minute average
19	Dew point temperature one-minute average
20	Relative humidity one-minute average
21	Vertical profile of mean dry bulb temperature
22	Vertical profile of mean wet bulb temperature
23	Vertical profile of mean dew point temperature
24	Vertical profile of mean relative humidity
25	Total solar radiation one-minute average

The sign convention for the Gill UVW anemometer and the system of coordinates used are shown in the following figure.



Gill UVW anemometer sign convention and system of coordinates

METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX VIII

BACKGROUND TETHERSONDE BALLOON SURVEYS: DATA TABLES

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15 January 1981

The results of the tethersonde balloon soundings performed during periods with no blasts-i.e., background meteorological data called BMD herein for convenience-are tabulated in the tables given in this appendix. They are presented in the sequence shown in the table below. A list of the data presented in each table, along with cross-references to the corresponding figures included in Appendix IX, is provided.

BACKGROUND TETHERSONDE BALLOON SURVEY SEQUENCE

DATE	TEST CODE TABLE INDEX	TETHERSONDE BALLOON SAMPLE PERIOD (CST)	MAXIMUM ALTITUDE (m)
04/22/80	BMD-22-1	18:44 - 18:57	157
04/23/80	BMD-23-1	05:58 - 06:12	196
04/24/80	BMD-24-1	10:07 - 10:27	170
	BMD-24-2	13:07 - 13:21	178
	BMD-24-3	16:00 - 16:04	60

DATA PRESENTED IN EACH TABLE

	Fig. # (see Appendix IX)
Sample time (CST)	given in all figures
Height	
Atmospheric pressure	1
Mean temperature	5
Relative humidity	7
Mixing ratio	8
Mean wind speed	2,4
Mean wind direction	3,4
Potential temperature	6

METEOROLOGICAL PARAMETERS WITHIN A FOREST CANOPY AT FORT POLK, LOUISIANA

APPENDIX IX

BACKGROUND TETHERSONDE BALLOON SURVEYS: FIGURES

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15 January 1981

All the results on the background meteorological data obtained during the tethersonde balloon surveys and which are tabulated in Appendix VIII are displayed in the figures given in this appendix. The results for each sample period, according to the sequence outlined in the table below, are portrayed in eight figures. In each one of these eight figures, the data for a different meteorological parameter are shown. The order in which these figures are presented is outlined in the list of figures given herein. Note that the wind rose is shown in several figures for the sake of clarity, so that no more than ten wind vectors (i.e., at ten different heights) are included in each figure.

BACKGROUND TETHERSONDE BALLOON SURVEY SEQUENCE

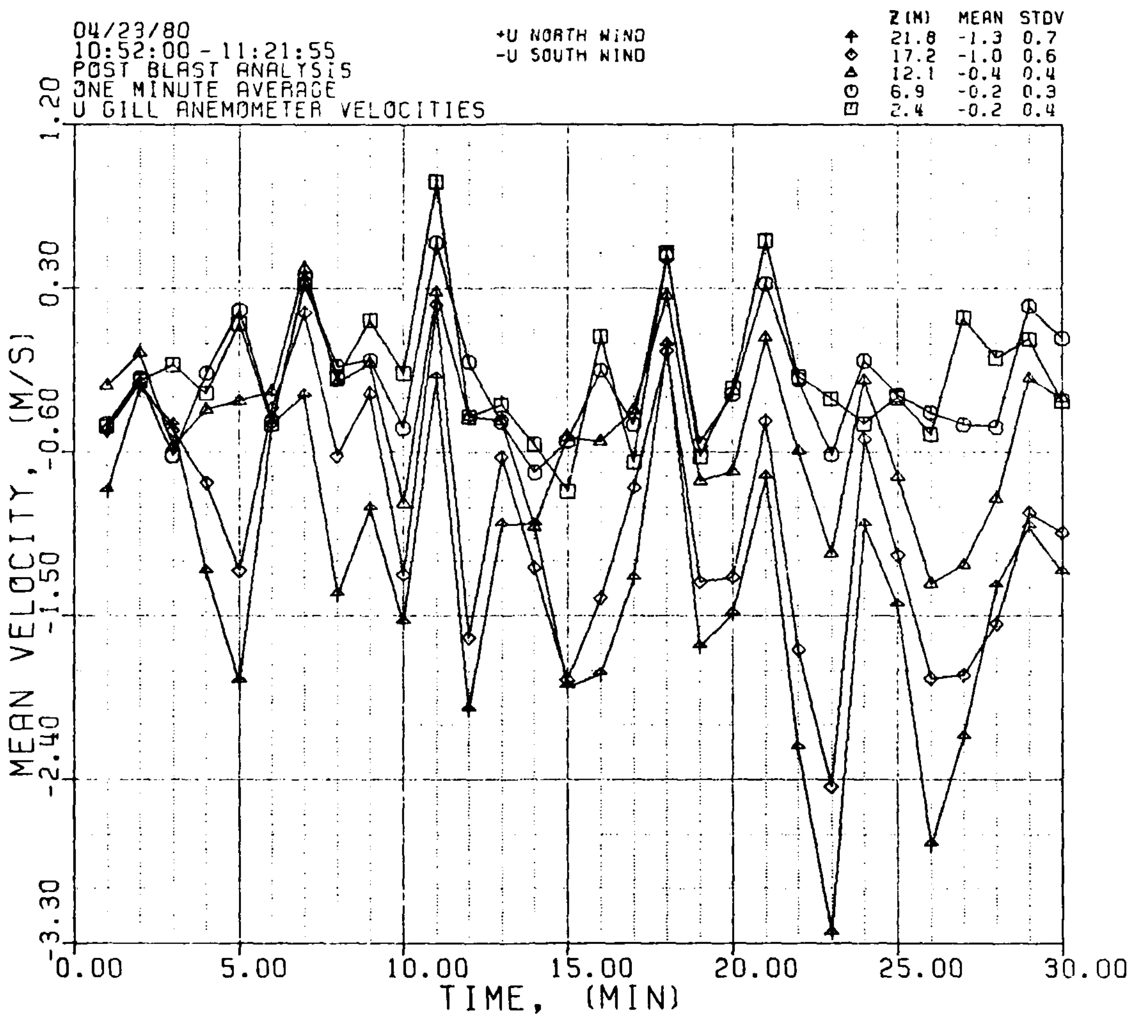
DATE	TEST CODE TABLE INDEX	TETHERSONDE BALLOON SAMPLE PERIOD (CST)	MAXIMUM ALTITUDE (m)
04/22/80	BMD-22-1	18:44 - 18:57	157
04/23/80	BMD-23-1	05:58 - 06:12	196
04/24/80	BMD-24-1	10:07 - 10:27	170
	BMD-24-2	13:07 - 13:21	178
	BMD-24-3	16:00 - 16:04	60

Fig. # List of Figures

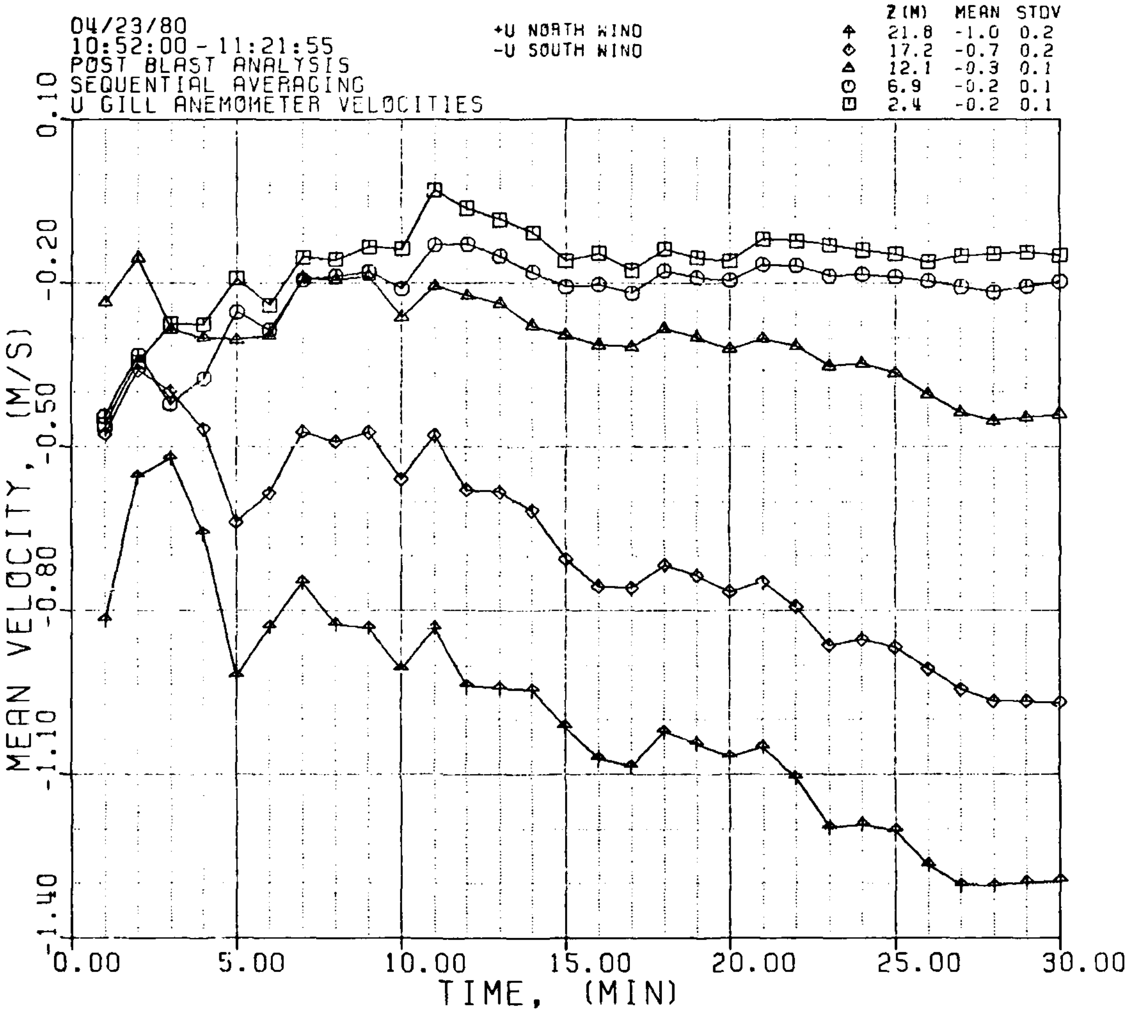
SUPPLEMENT I

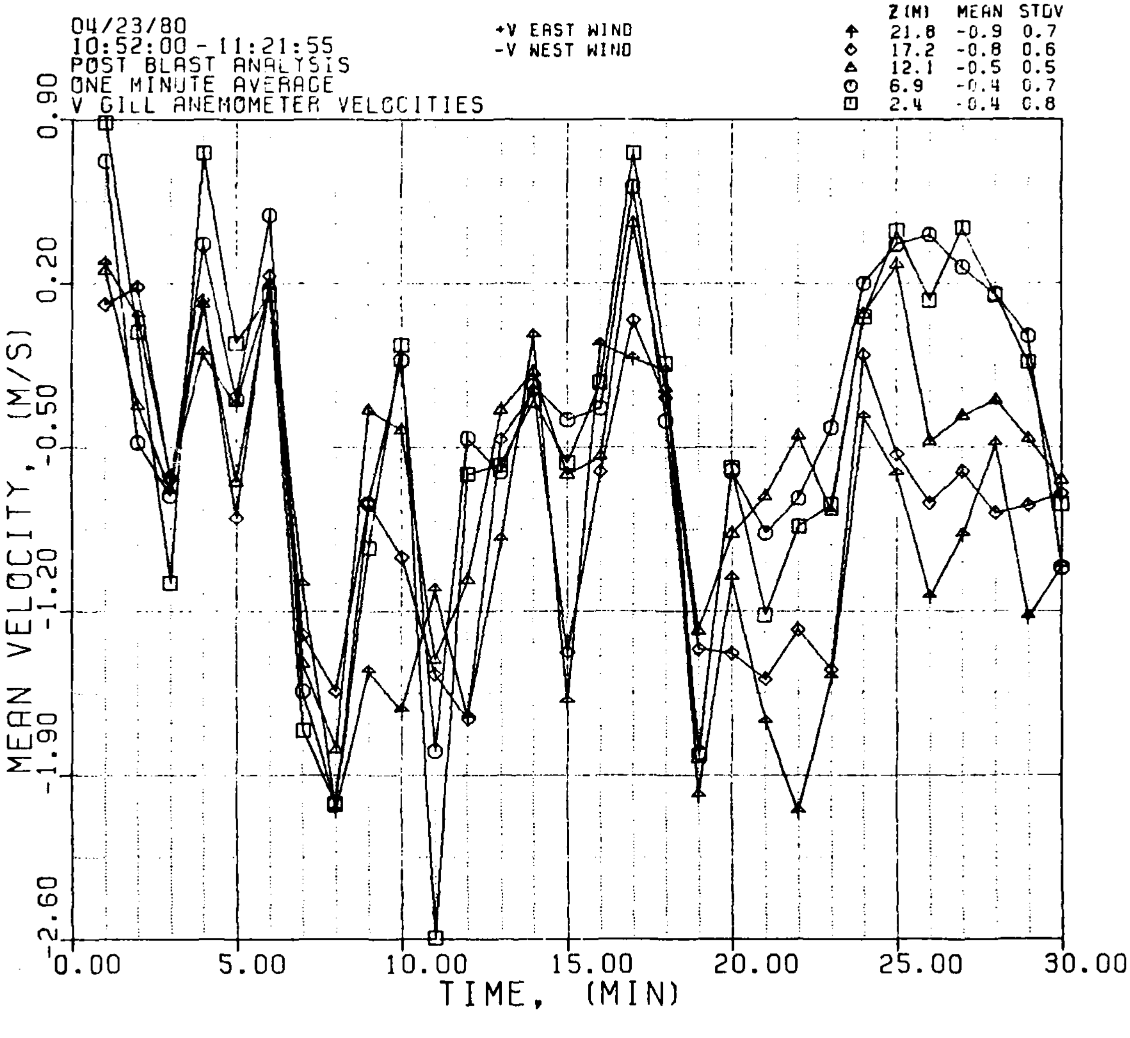
SAMPLE OF A POST-BLAST SAMPLE PERIOD: FIGURES

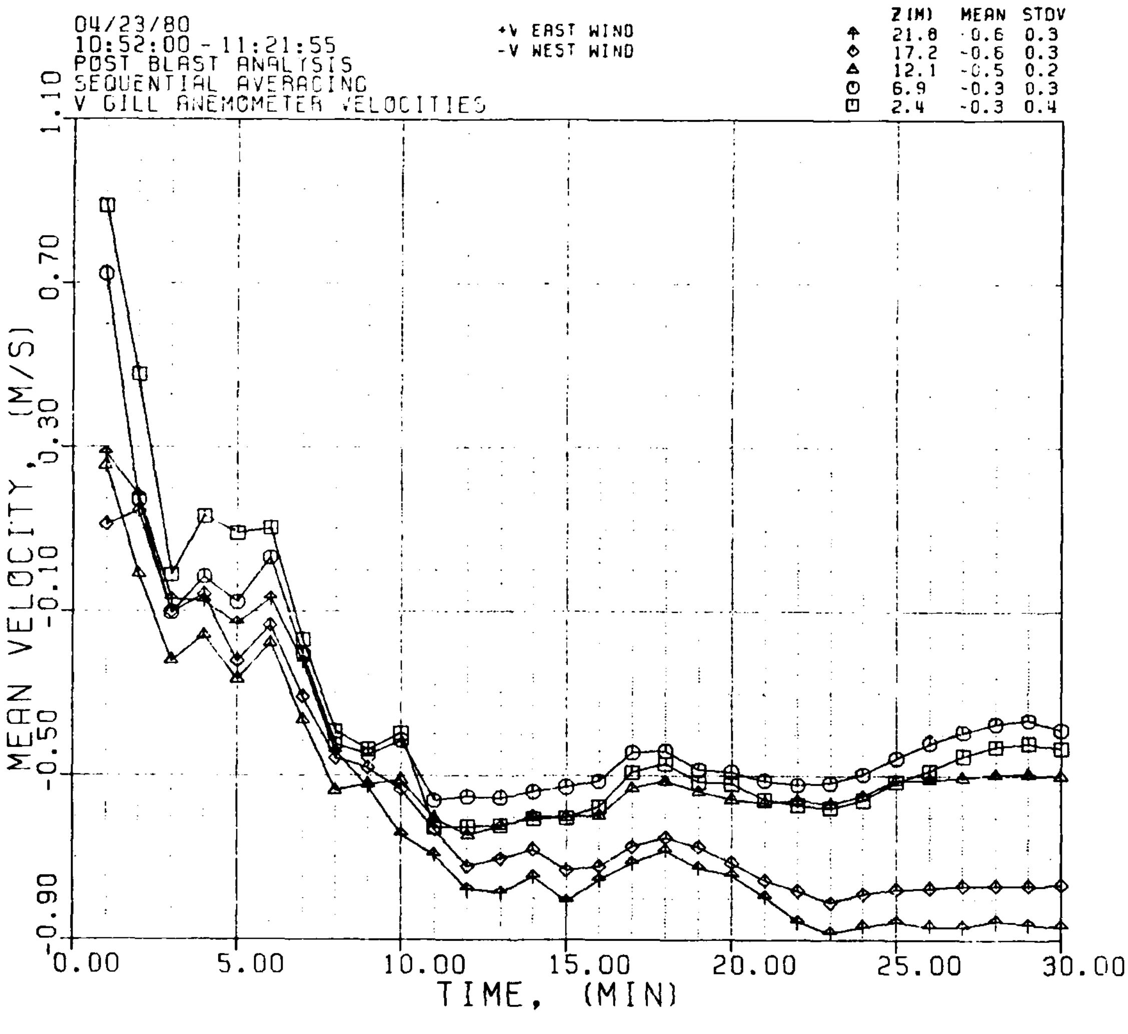
In this supplement, figures of the results for one post-blast sample period presented in Appendix III, Sect. III.6/04-23-1980, Test Code 27-C9-AB, are given. The order in which these figures are shown is listed below.



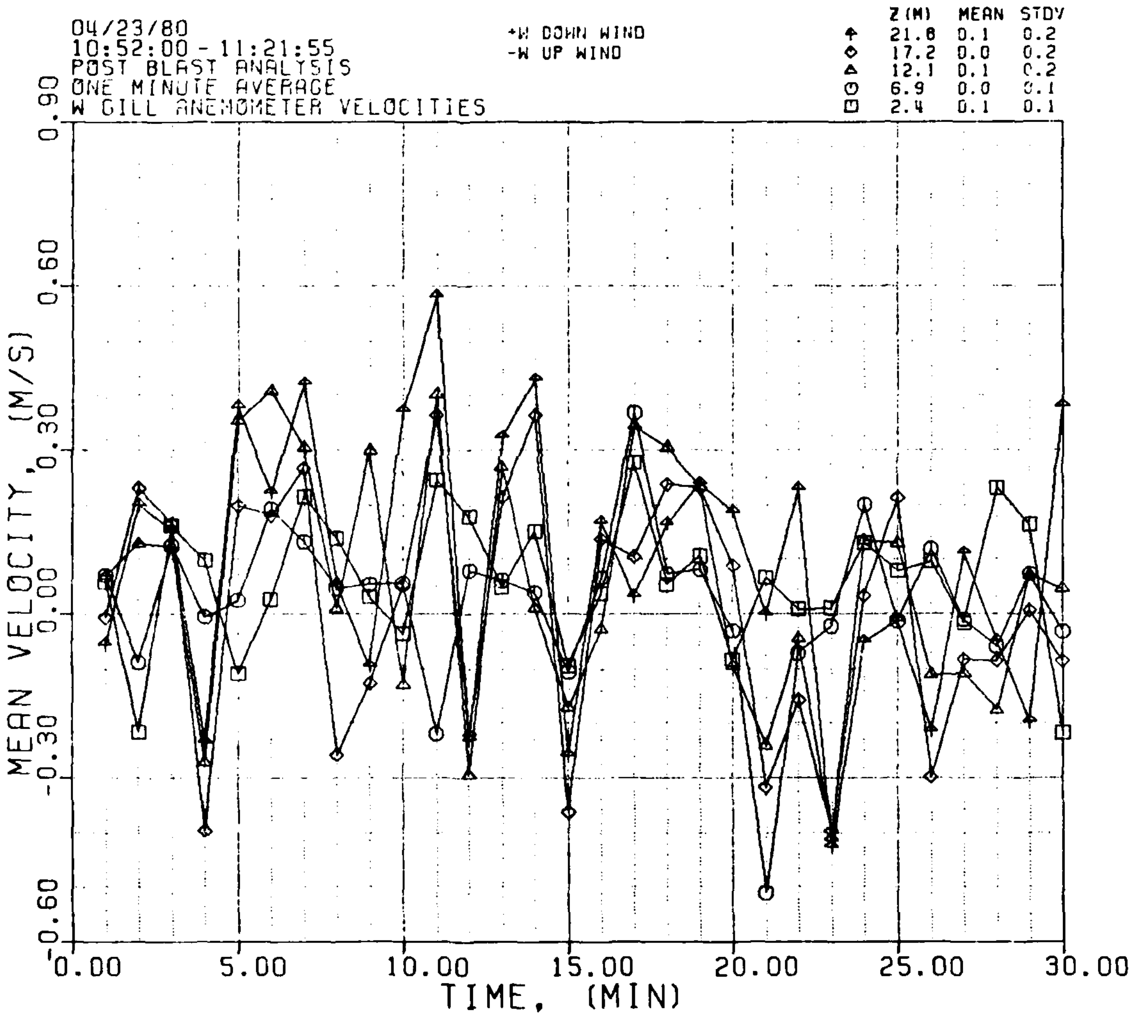
04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
U GILL ANEMOMETER VELOCITIES
+U NORTH WIND
-U SOUTH WIND
Z (M) MEAN STDV
21.8 -1.3 0.7
17.2 -1.0 0.6
12.1 -0.4 0.4
6.9 -0.2 0.3
2.4 -0.2 0.4
MEAN VELOCITY, (M/S)
1.20
0.30
-0.60
-1.50
-2.40
-3.30
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

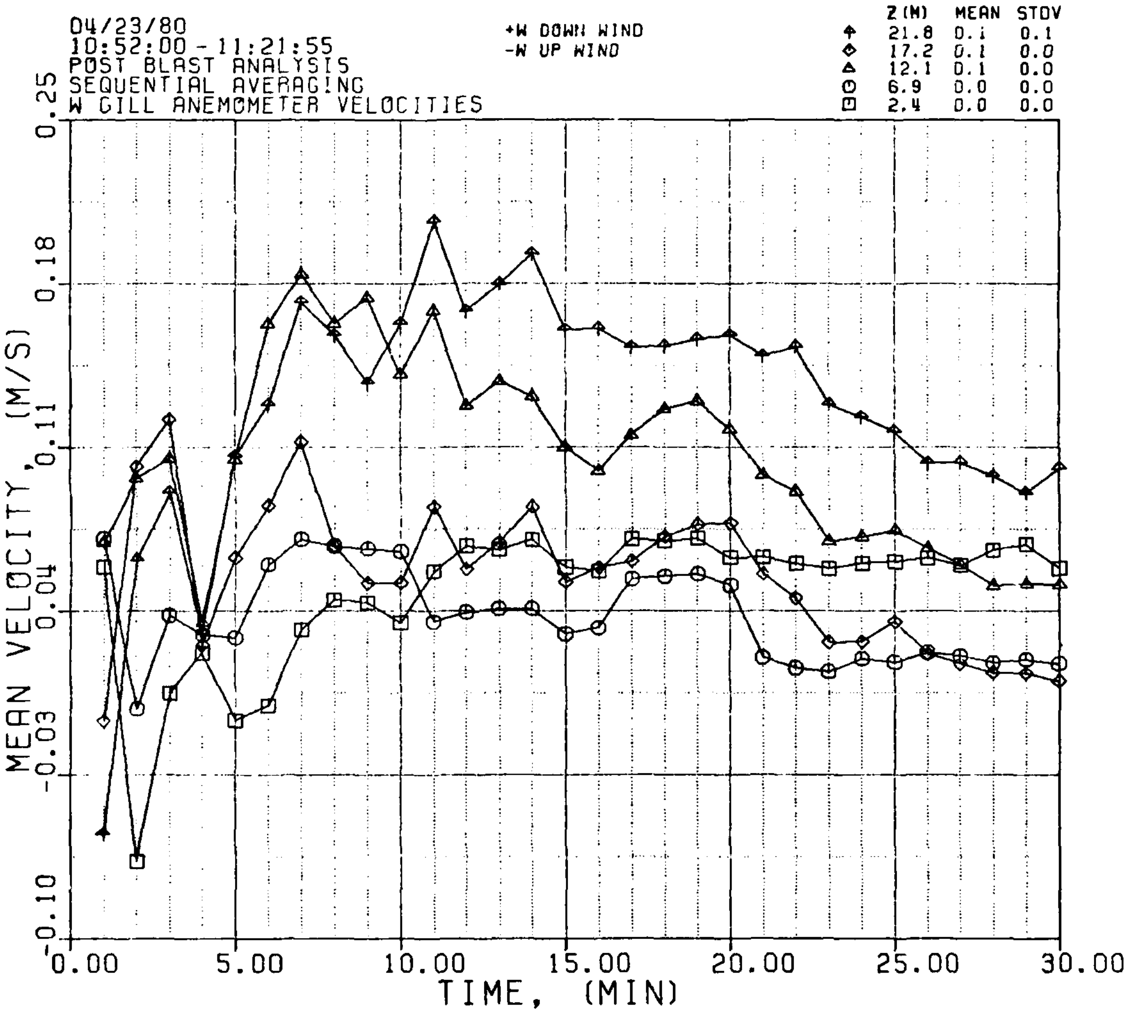

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
SEQUENTIAL AVERAGING
U GILL ANEMOMETER VELOCITIES
+U NORTH WIND
-U SOUTH WIND
Z(M) MEAN STDV
21.8 -1.0 0.2
17.2 -0.7 0.2
12.1 -0.3 0.1
6.9 -0.2 0.1
2.4 -0.2 0.1
MEAN VELOCITY, (M/S)
0.10
-0.20
-0.50
-0.80
-1.10
-1.40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

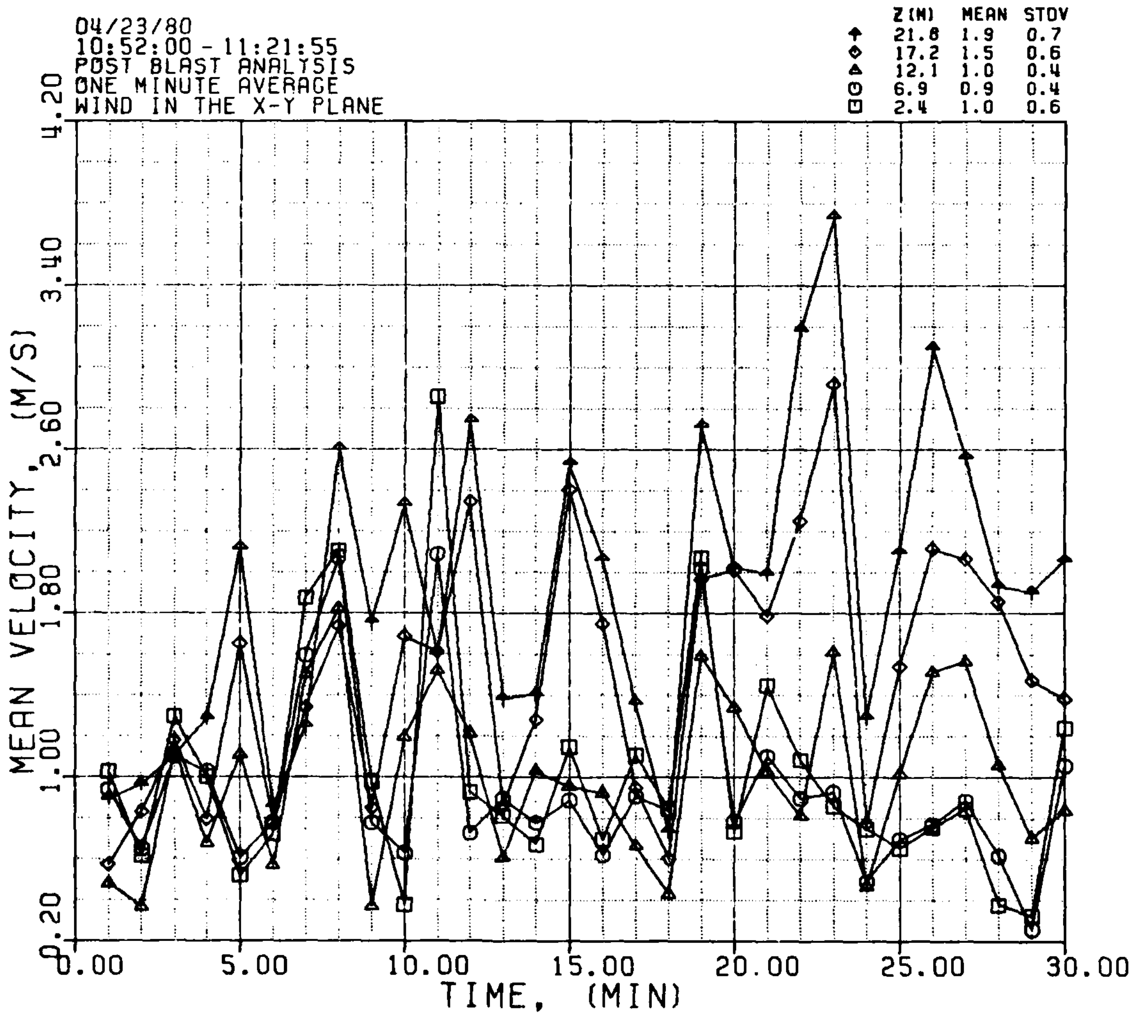

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
V GILL ANEMOMETER VELOCITIES
+V EAST WIND
-V WEST WIND
Z(M) MEAN STDV
21.8 -0.9 0.7
17.2 -0.8 0.6
12.1 -0.5 0.5
6.9 -0.4 0.7
2.4 -0.4 0.8
MEAN VELOCITY, (M/S)
0.90
0.20
-0.50
-1.20
-1.90
-2.60
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

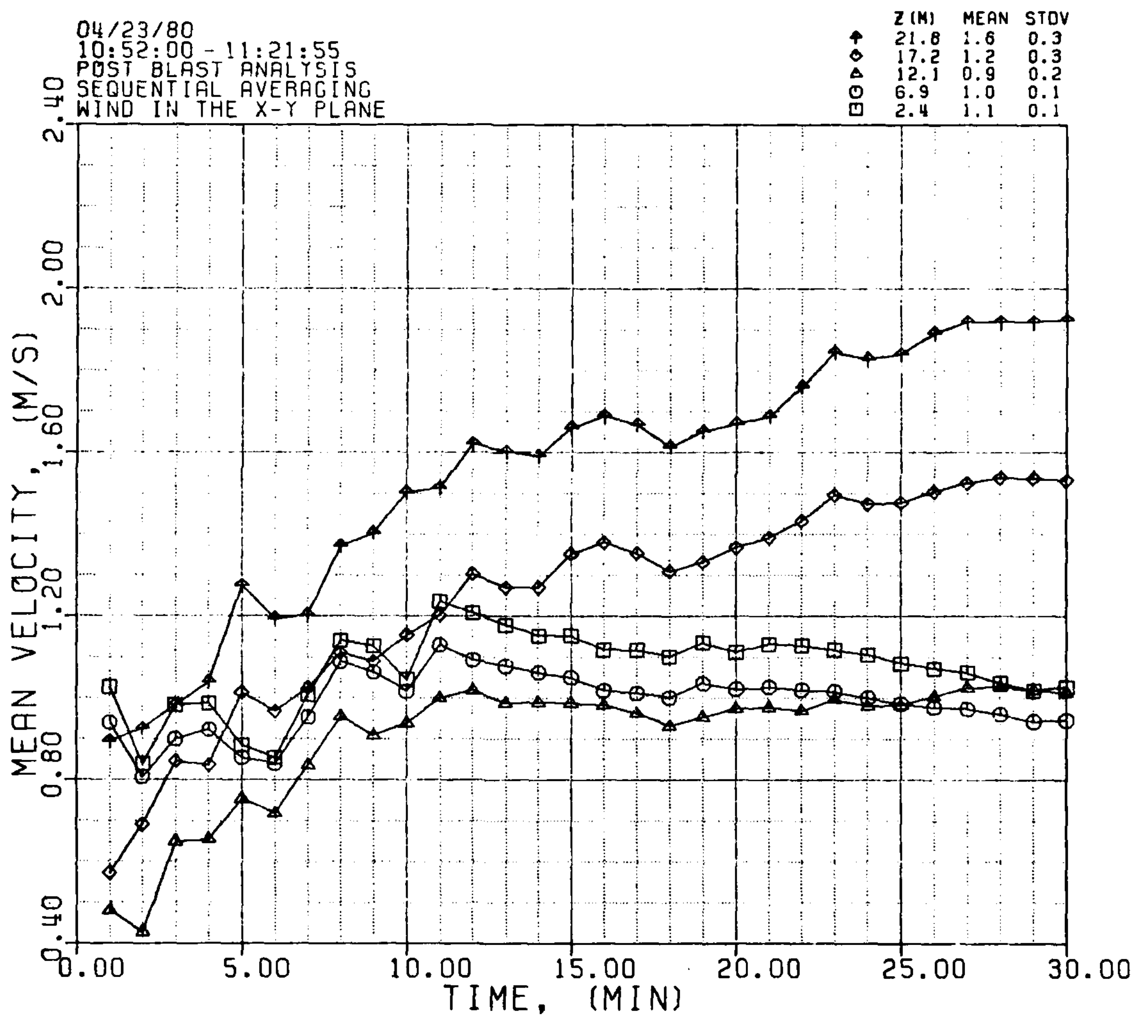


04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
SEQUENTIAL AVERAGING
V GILL ANEMOMETER VELOCITIES
+V EAST WIND
-V WEST WIND
Z (M) MEAN STDV
21.8 -0.6 0.3
17.2 -0.6 0.3
12.1 -0.5 0.2
6.9 -0.3 0.3
2.4 -0.3 0.4
MEAN VELOCITY, (M/S)
1.10
0.70
0.30
-0.10
-0.50
-0.90
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

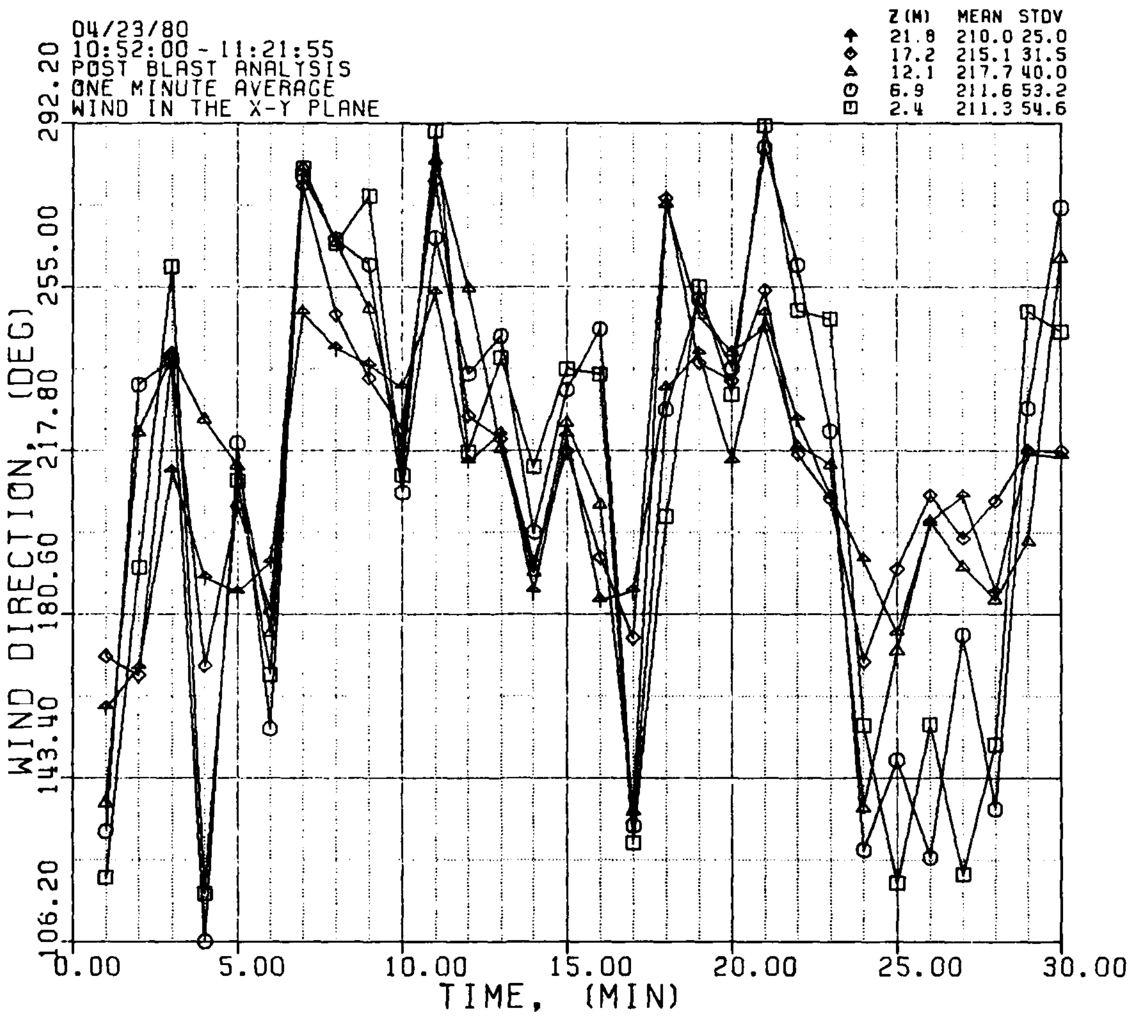

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
W GILL ANEMOMETER VELOCITIES
+W DOWN WIND
-W UP WIND
Z (M) MEAN STDV
21.8 0.1 0.2
17.2 0.0 0.2
12.1 0.1 0.2
6.9 0.0 0.1
2.4 0.1 0.1
MEAN VELOCITY, (M/S)
TIME, (MIN)
0.90
0.60
0.30
0.00
-0.30
-0.60
0.00
5.00
10.00
15.00
20.00
25.00
30.00

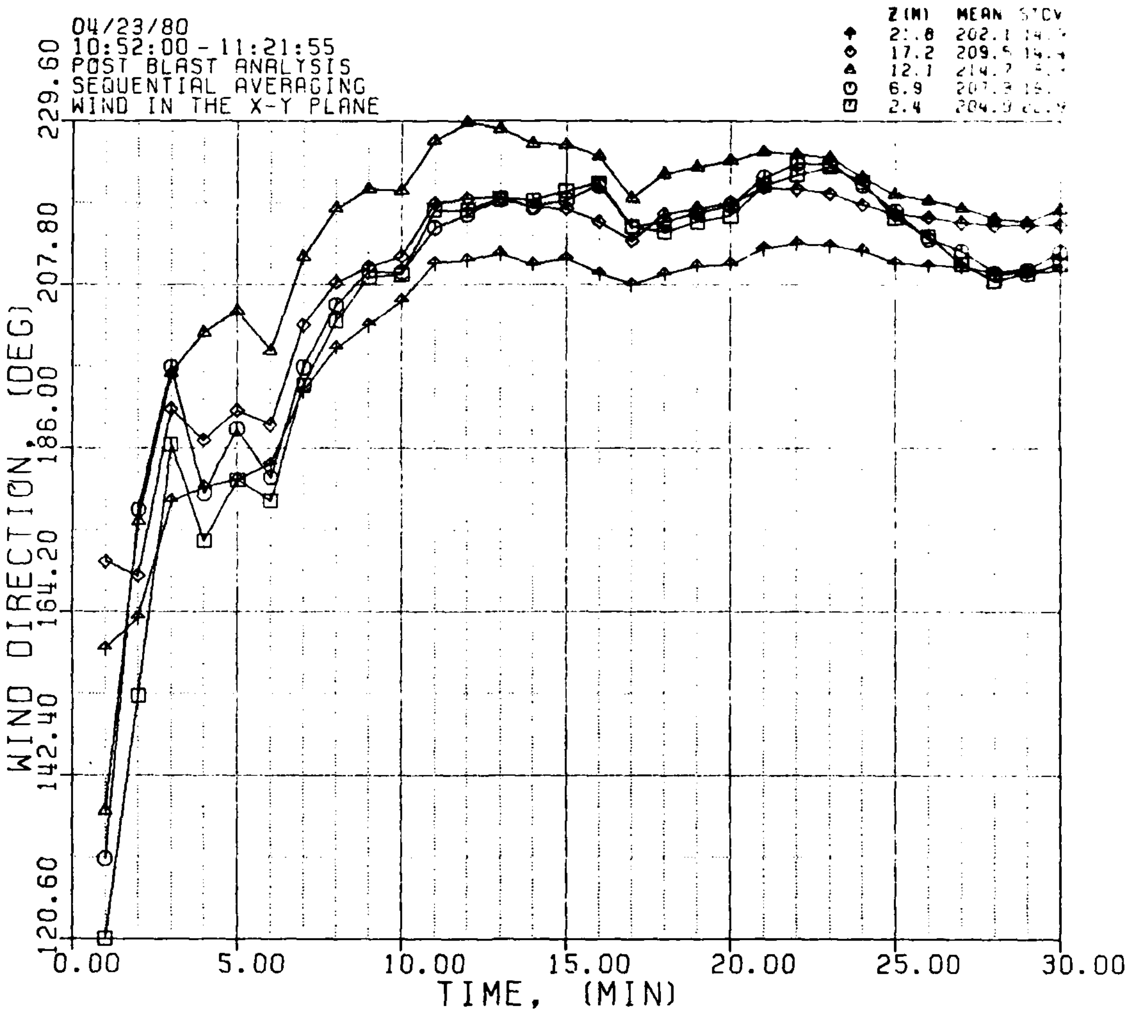

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
SEQUENTIAL AVERAGING
W GILL ANEMOMETER VELOCITIES
+W DOWN WIND
-W UP WIND
Z (M) MEAN STDV
21.8 0.1 0.1
17.2 0.1 0.0
12.1 0.1 0.0
6.9 0.0 0.0
2.4 0.0 0.0
MEAN VELOCITY, (M/S)
0.25
0.18
0.11
0.04
-0.03
-0.10
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

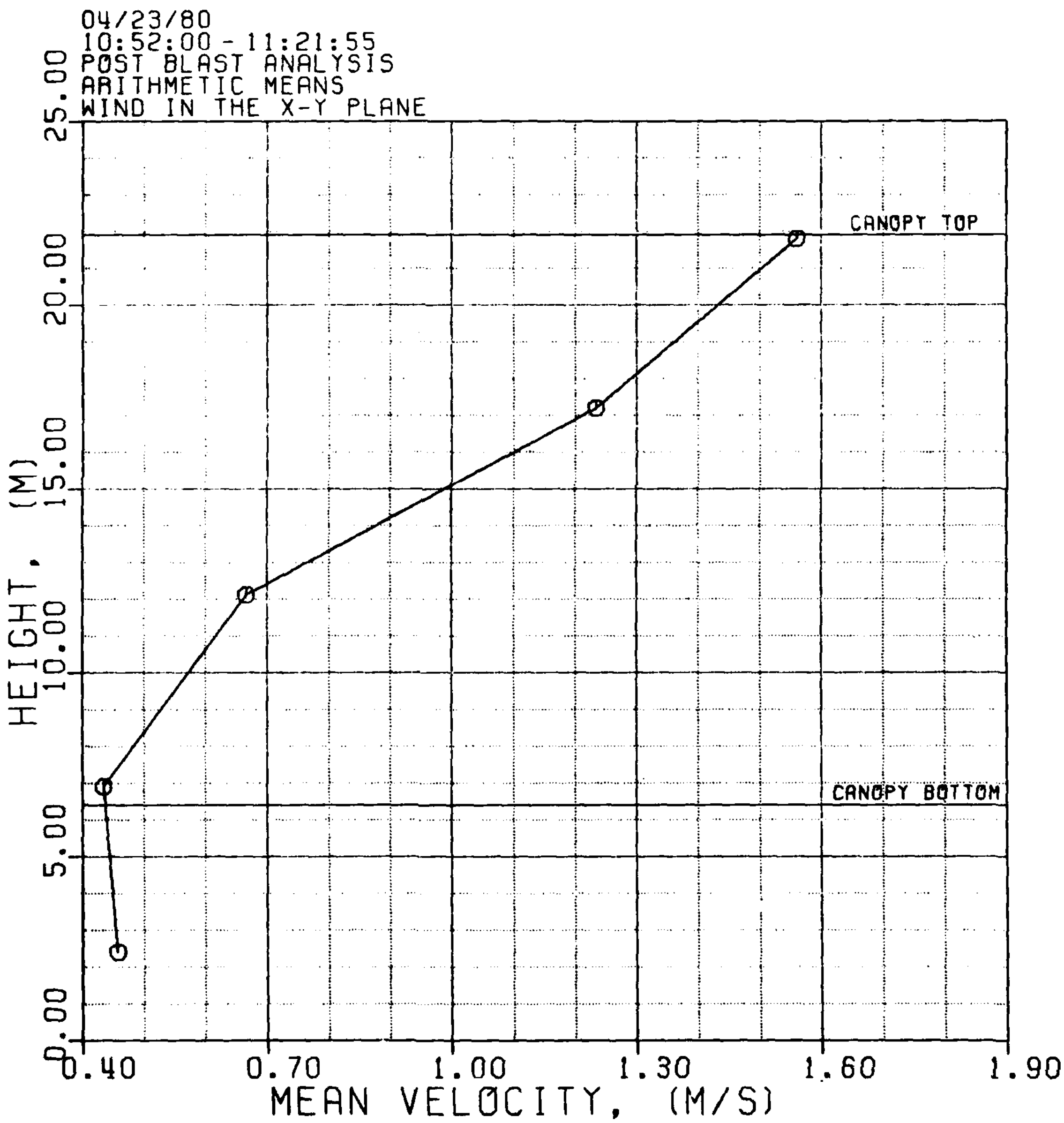

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
WIND IN THE X-Y PLANE
Z(M) MEAN STDV
21.8 1.9 0.7
17.2 1.5 0.6
12.1 1.0 0.4
6.9 0.9 0.4
2.4 1.0 0.6
MEAN VELOCITY, (M/S)
0.20
1.00
1.80
2.60
3.40
4.20
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

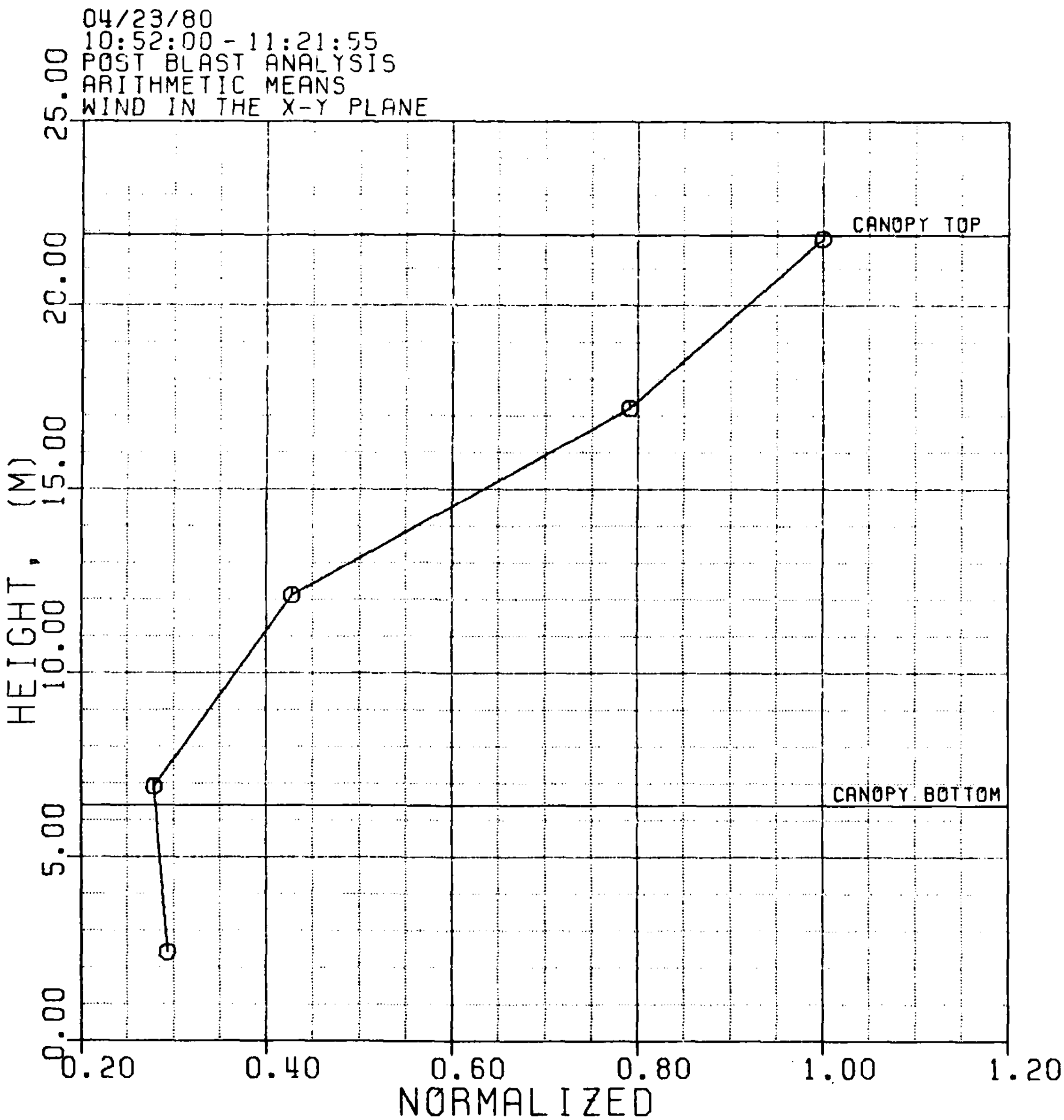


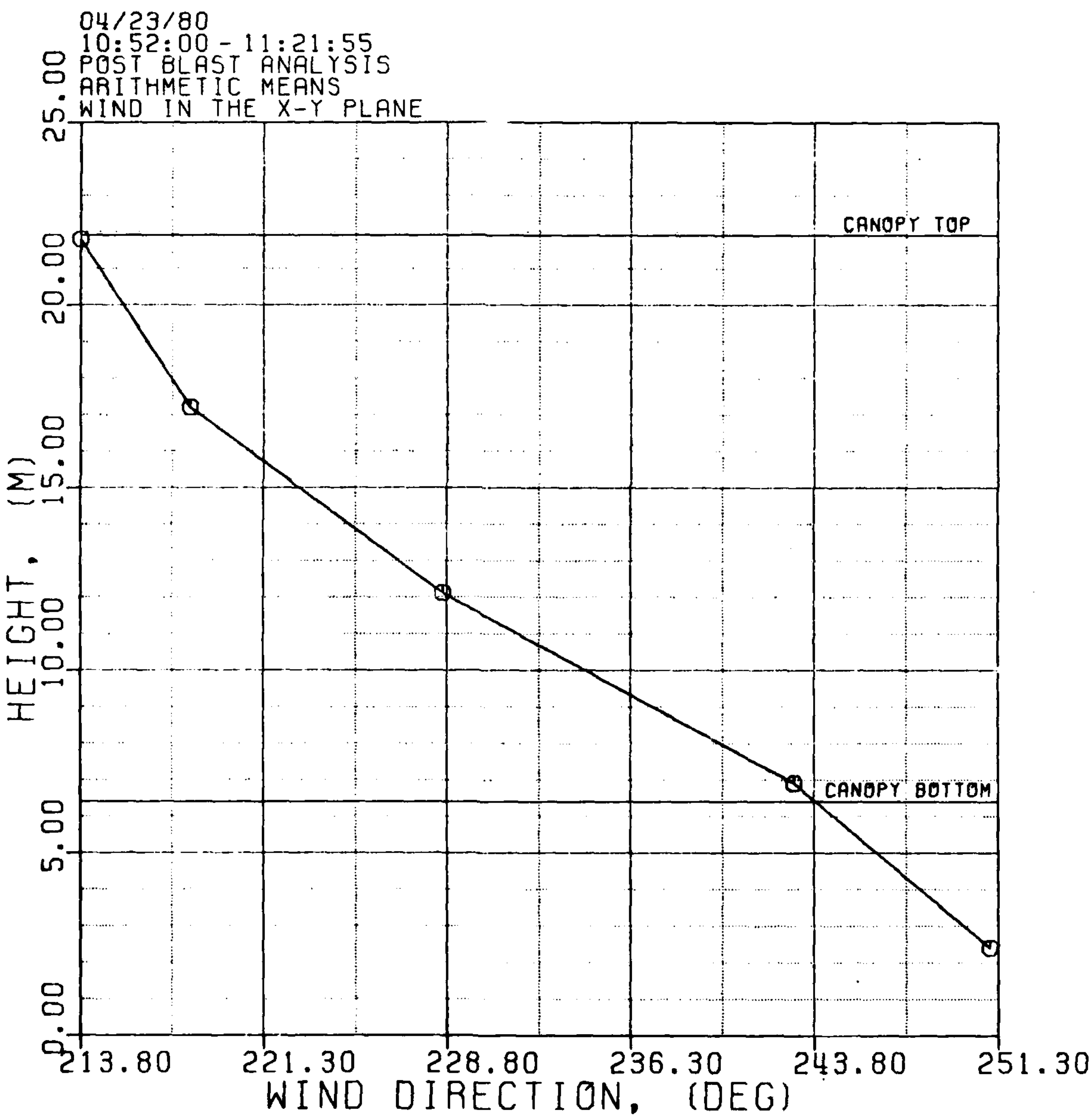
04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
SEQUENTIAL AVERAGING
WIND IN THE X-Y PLANE
Z (M) MEAN STDV
21.8 1.6 0.3
17.2 1.2 0.3
12.1 0.9 0.2
6.9 1.0 0.1
2.4 1.1 0.1
MEAN VELOCITY, (M/S)
0.40
0.80
1.20
1.60
2.00
2.40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

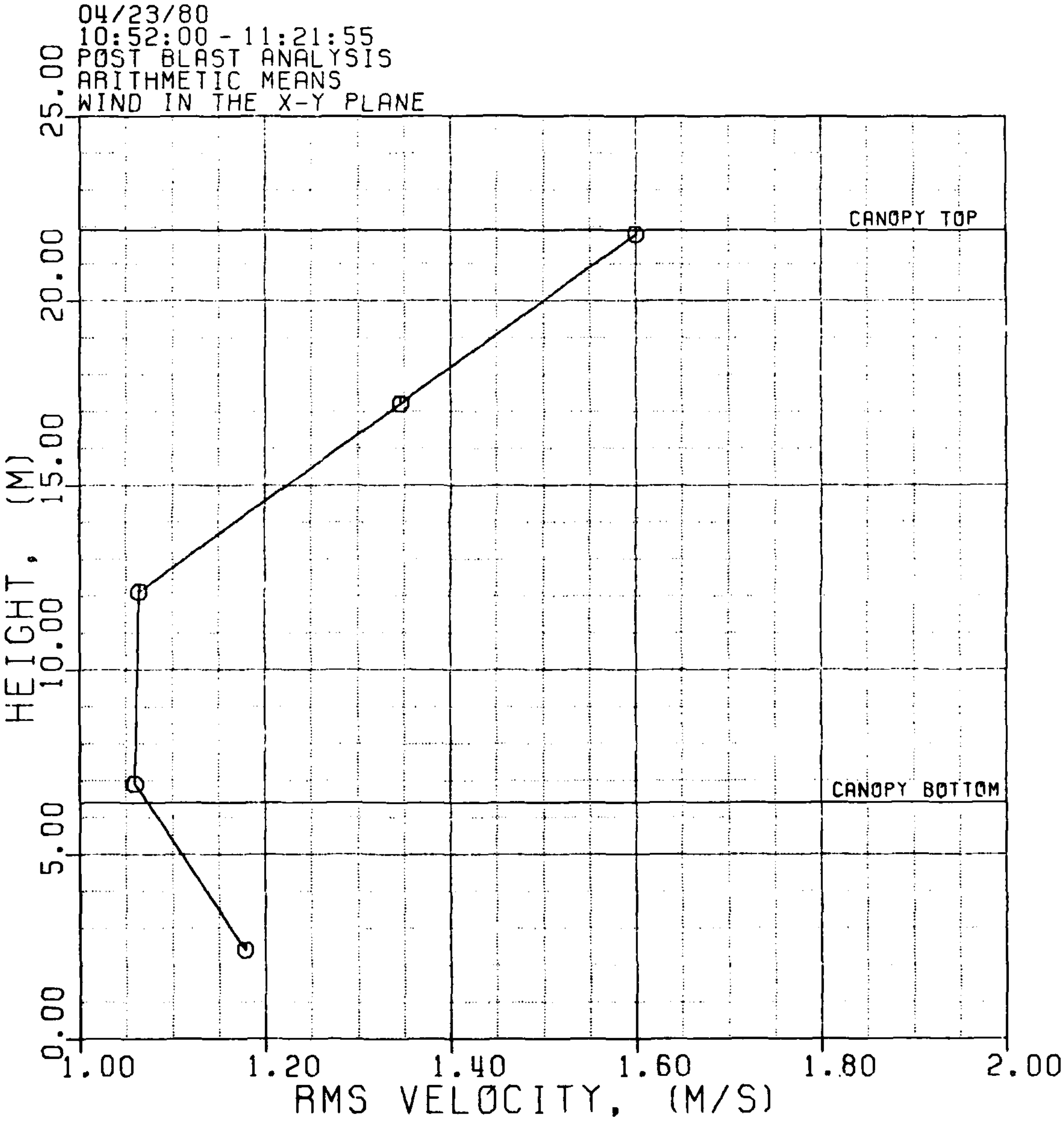

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
WIND IN THE X-Y PLANE
Z(M) MEAN STDV
21.8 210.0 25.0
17.2 215.1 31.5
12.1 217.7 40.0
6.9 211.6 53.2
2.4 211.3 54.6
WIND DIRECTION, (DEG)
292.20
255.00
217.80
180.60
143.40
106.20
TIME, (MIN)
0.00
5.00
10.00
15.00
20.00
25.00
30.00


04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
SEQUENTIAL AVERAGING
WIND IN THE X-Y PLANE
Z(M) MEAN
17.2 209.
12.1
6.9
2.4
229.60
207.80
186.00
164.20
142.40
120.60
WIND DIRECTION, (DEG)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

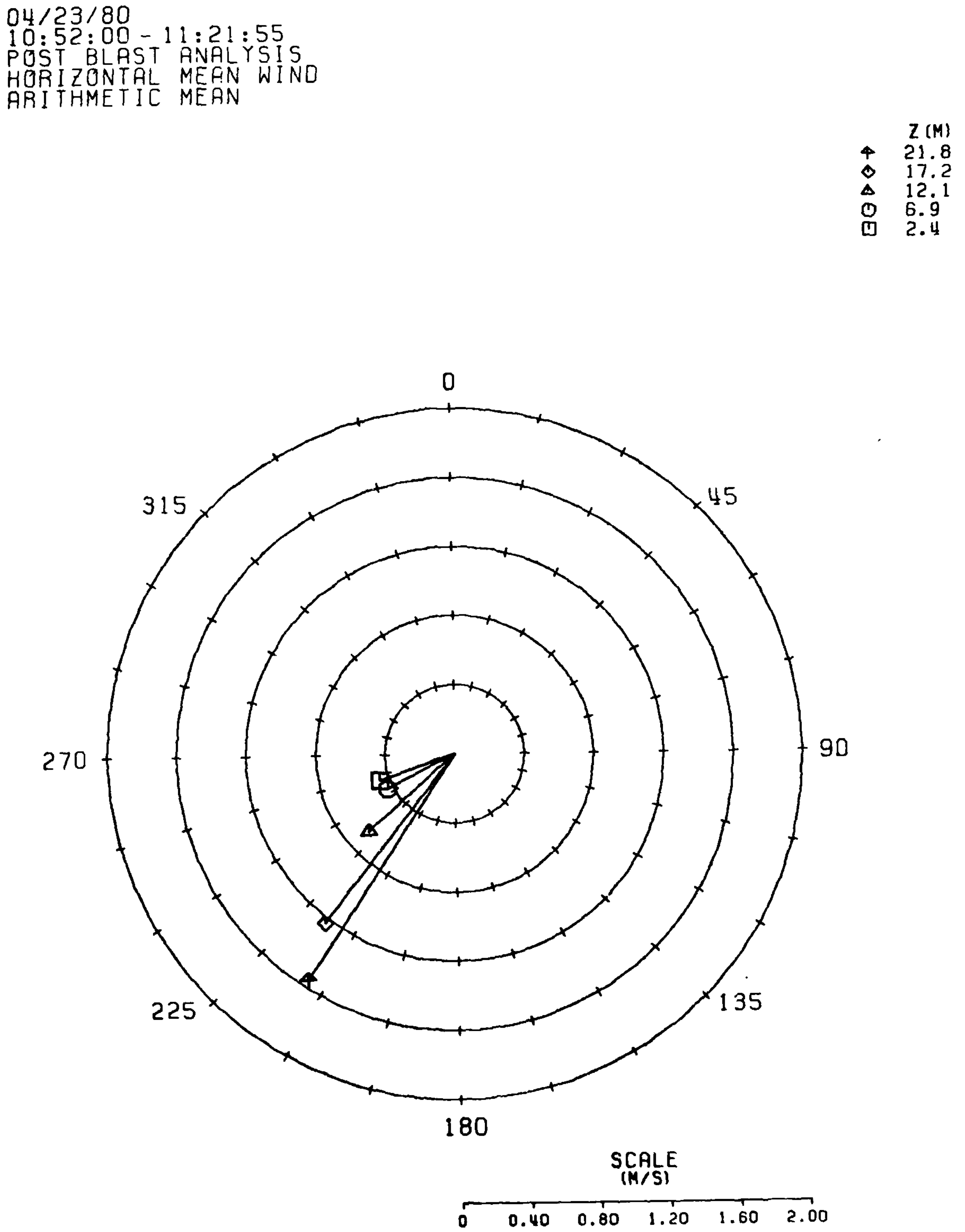

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
0.40
0.70
1.00
1.30
1.60
1.90
MEAN VELOCITY, (M/S)


04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
0.20
0.40
0.60
0.80
1.00
1.20
NORMALIZED

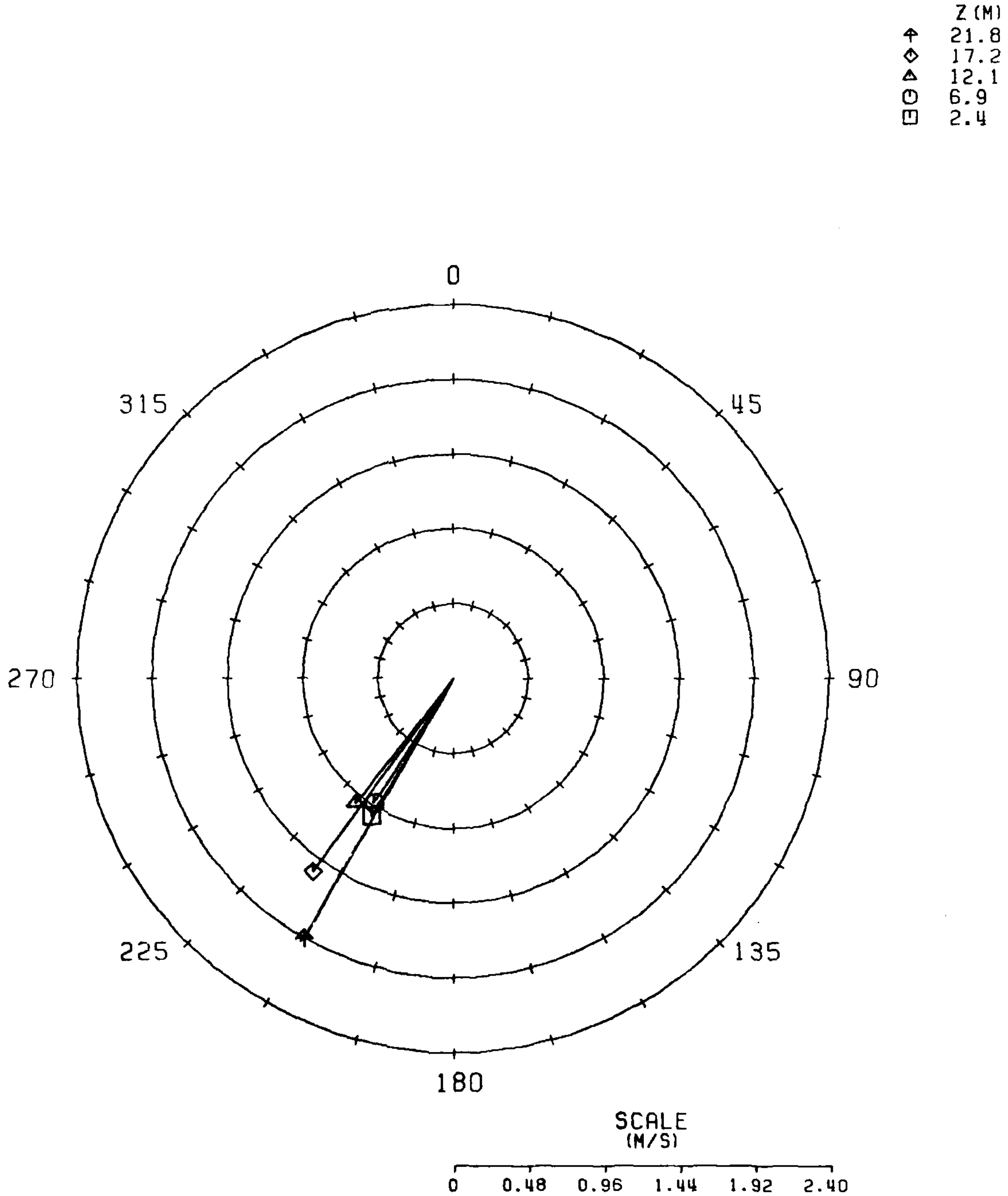

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
213.80
221.30
228.80
236.30
243.80
251.30
WIND DIRECTION, (DEG)

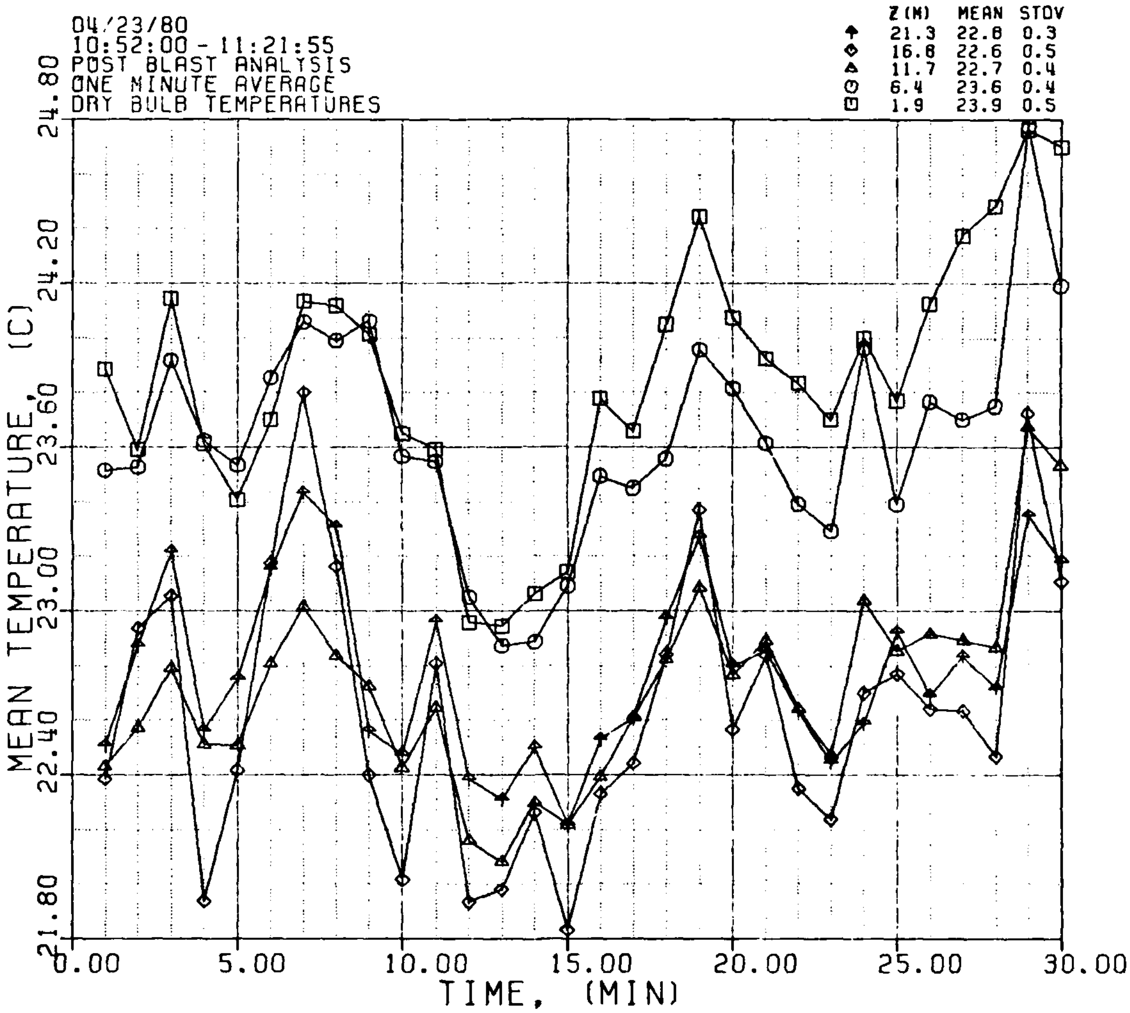


04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
1.00
1.20
1.40
1.60
1.80
2.00
RMS VELOCITY, (M/S)

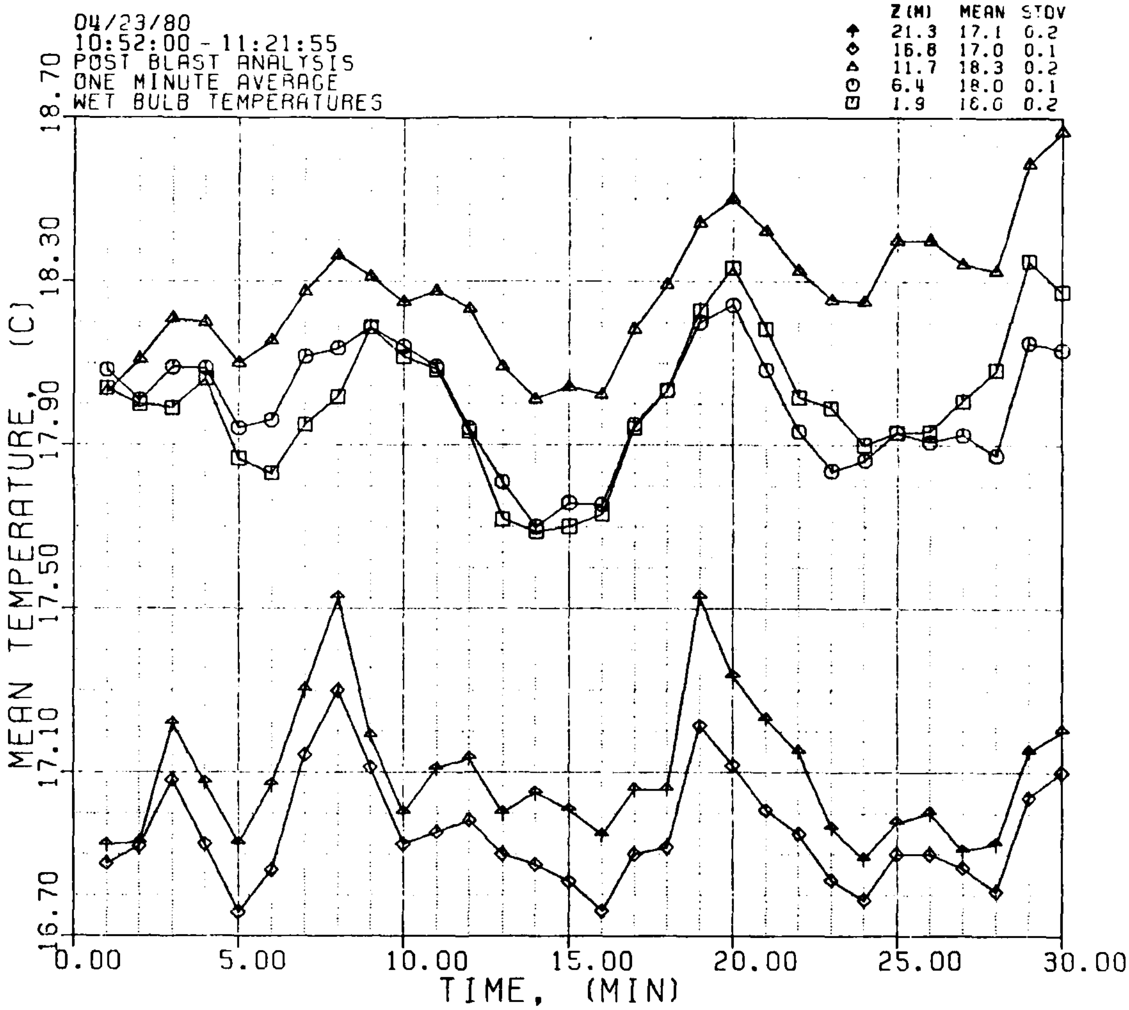

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
HORIZONTAL MEAN WIND
ARITHMETIC MEAN
Z (M)
21.8
17.2
12.1
6.9
2.4
0
45
90
135
180
225
270
315
SCALE
(M/S)
0
0.40
0.80
1.20
1.60
2.00

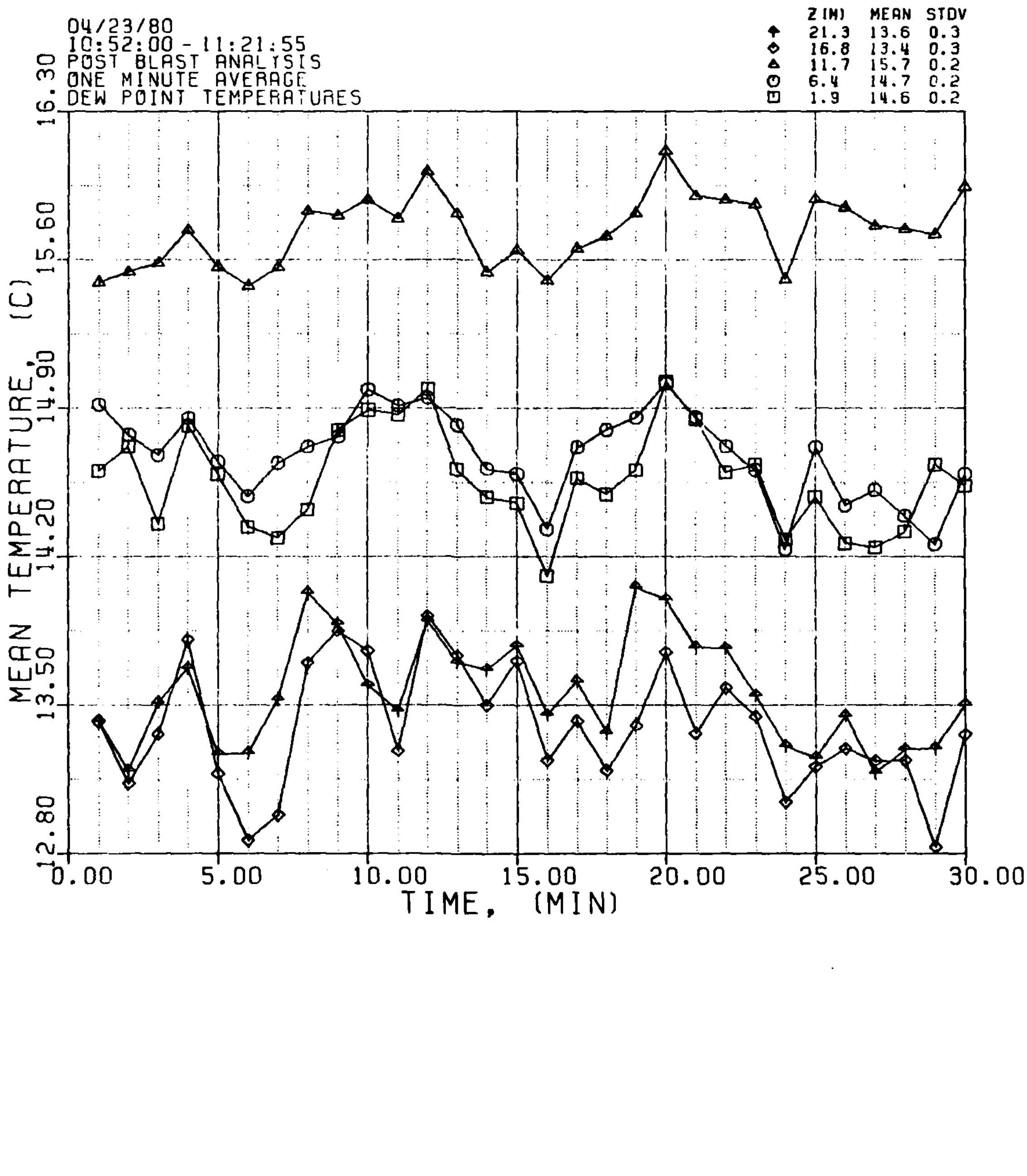
04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
HORIZONTAL MEAN WIND
MEAN OF INSTANTANEOUS WIND VECTORS

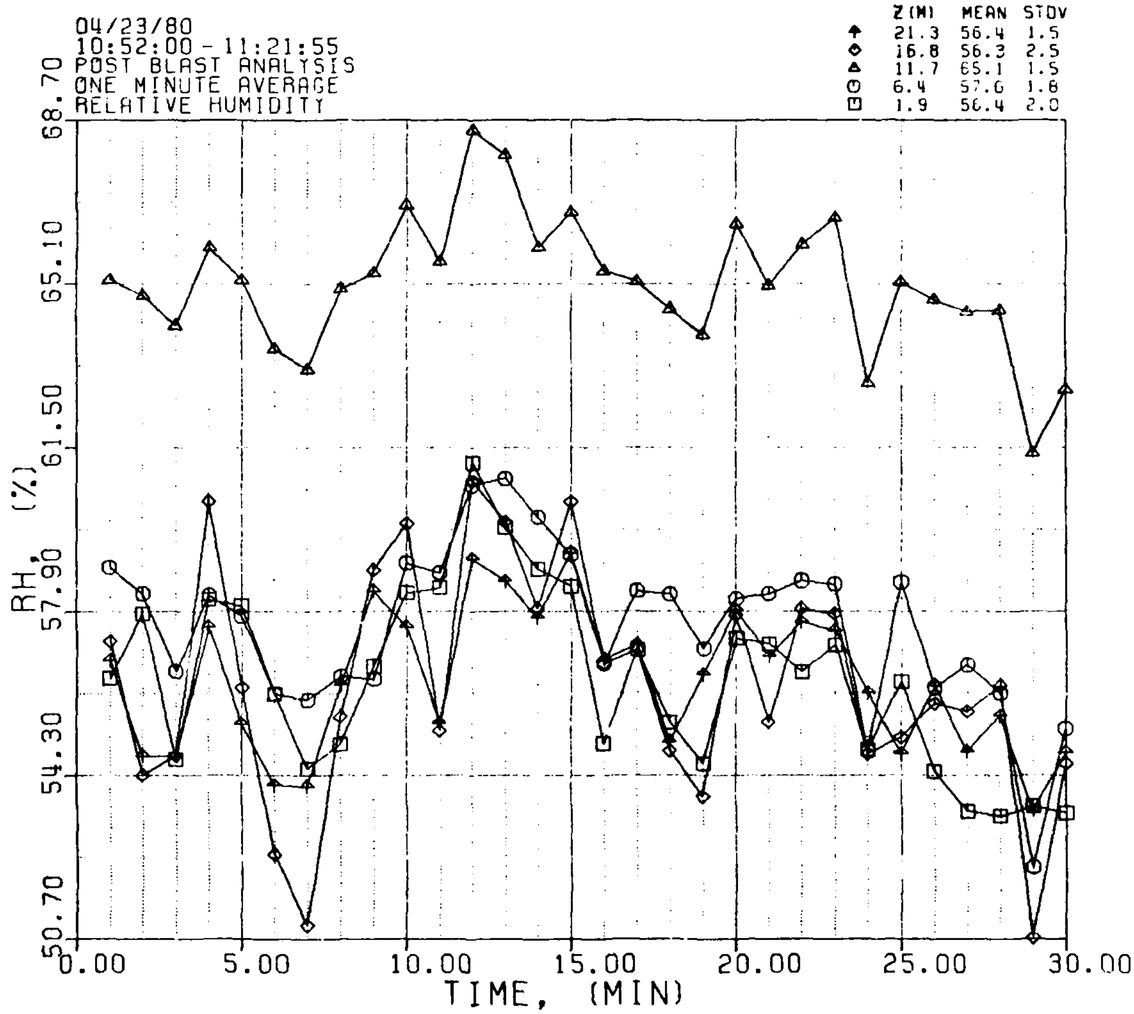


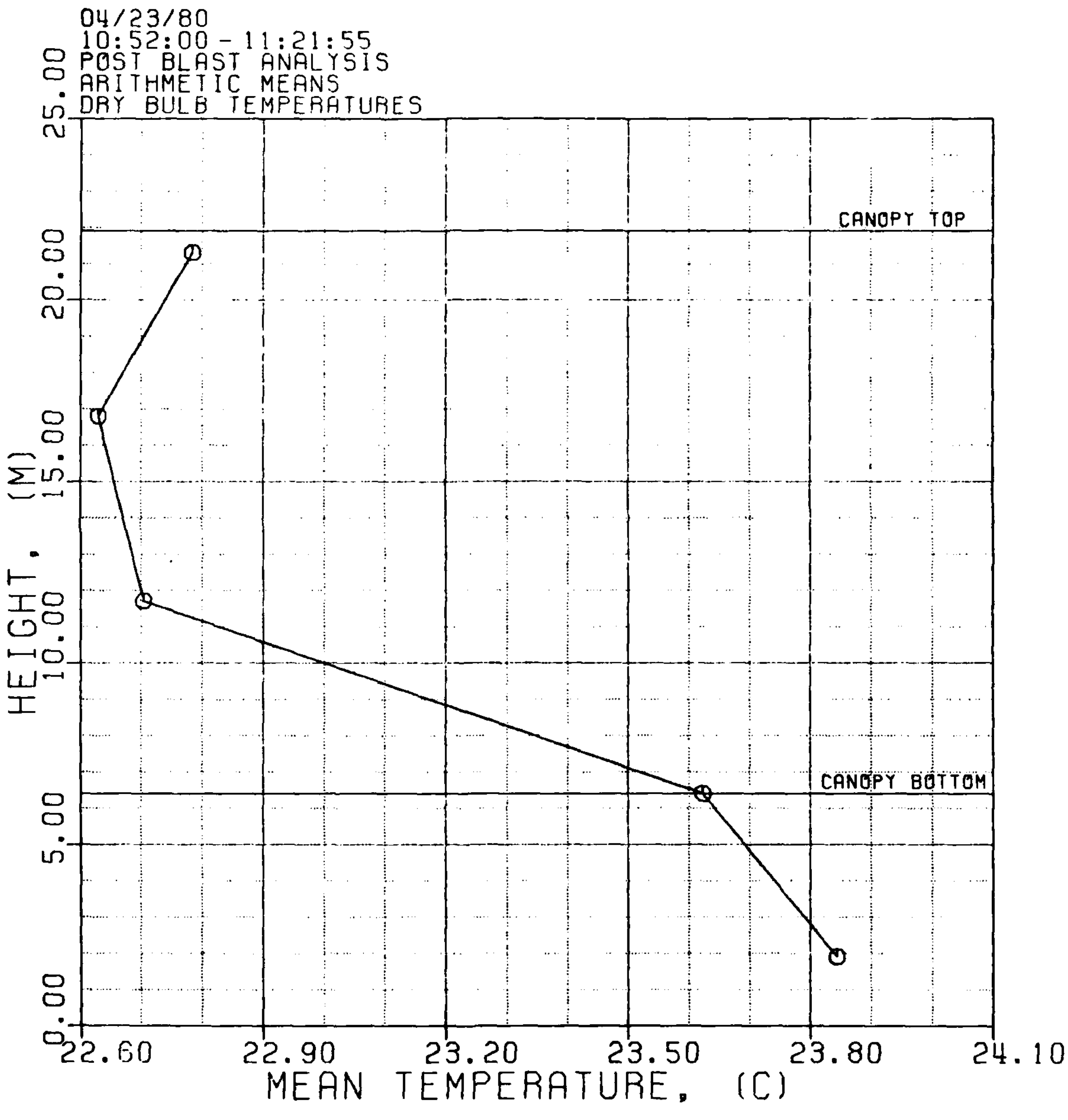


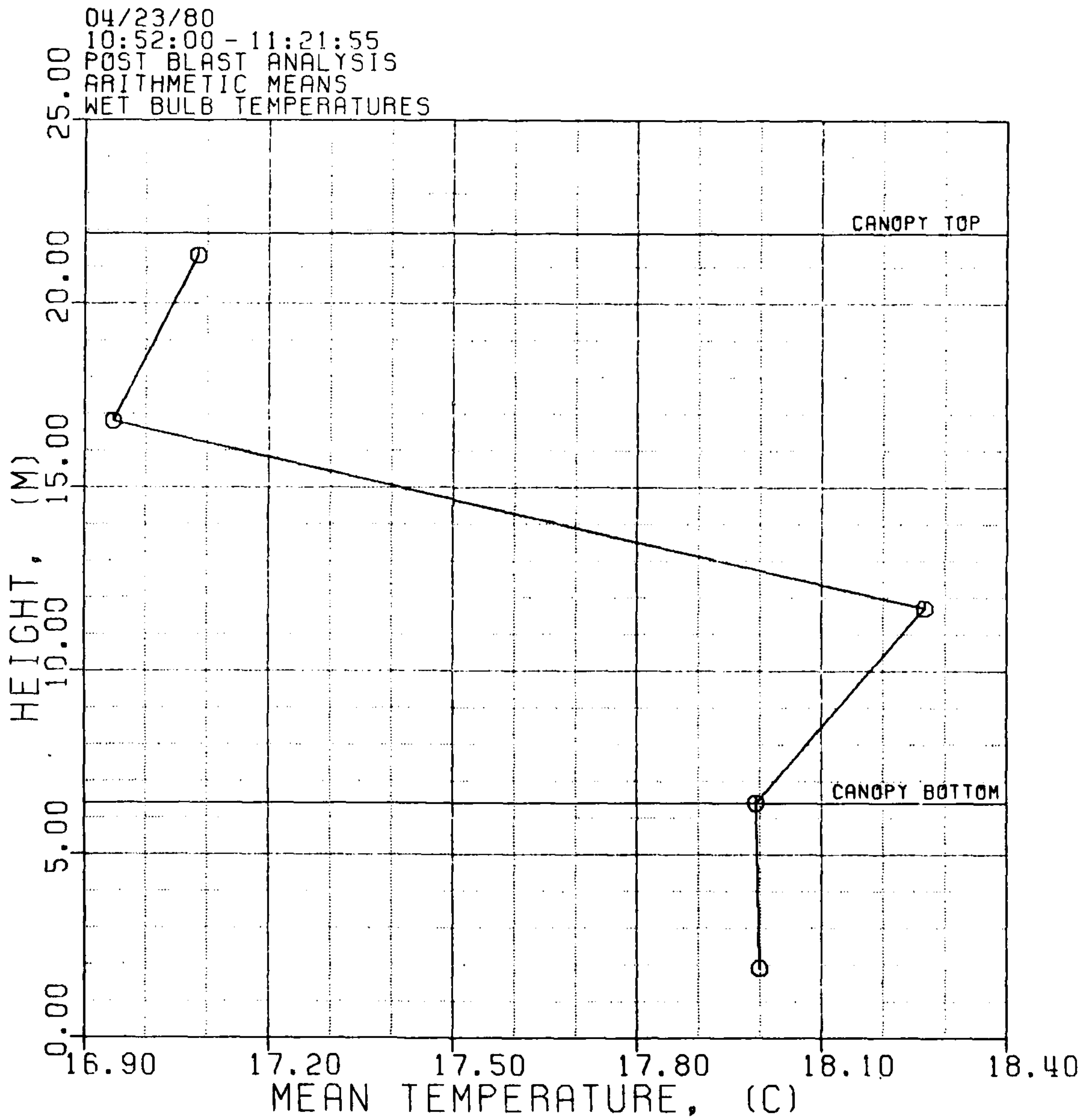
04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
DRY BULB TEMPERATURES
Z (M) MEAN STDV
21.3 22.8 0.3
16.8 22.6 0.5
11.7 22.7 0.4
6.4 23.6 0.4
1.9 23.9 0.5
MEAN TEMPERATURE, (C)
21.80
22.40
23.00
23.60
24.20
24.80
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

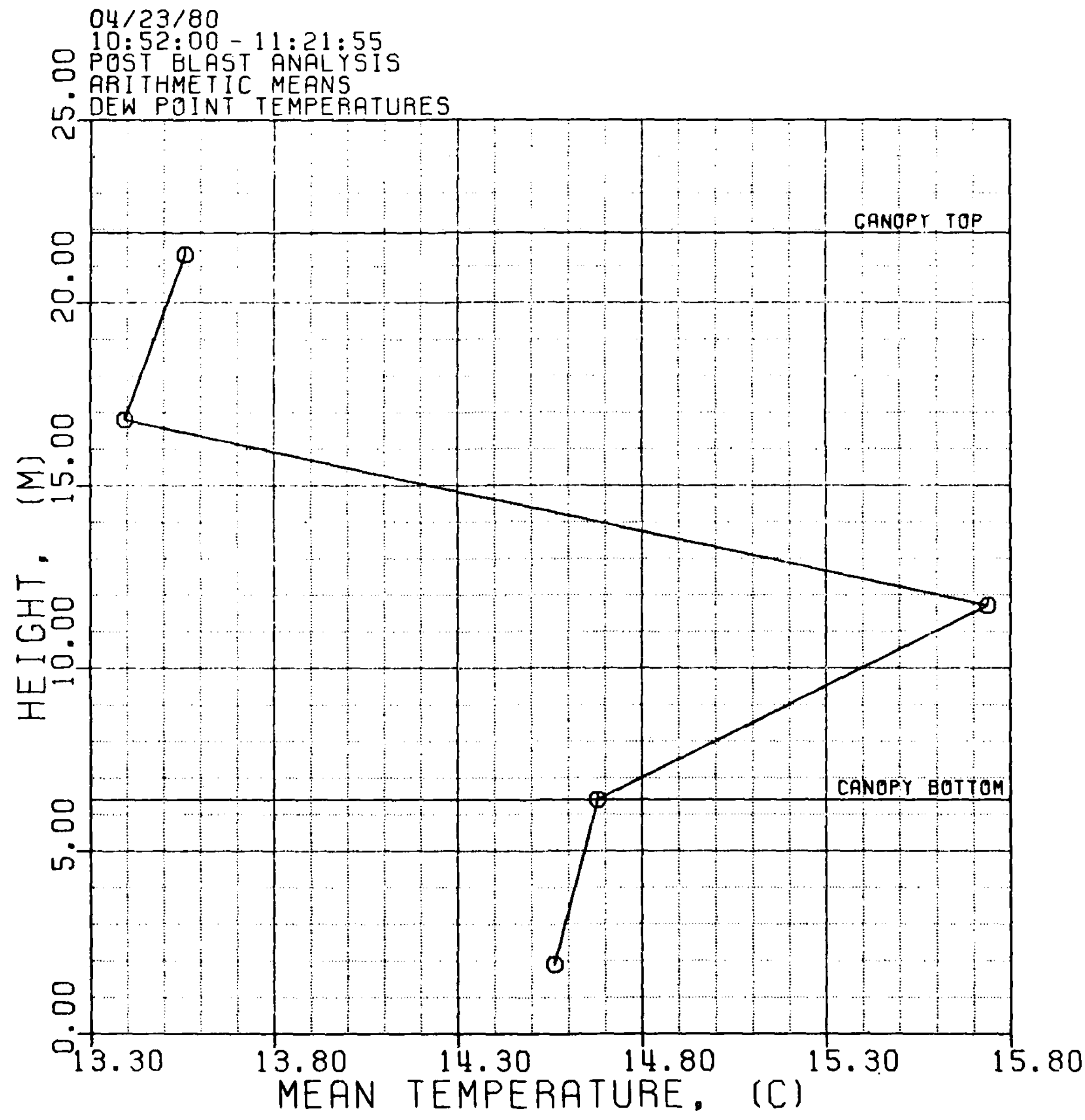

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
WET BULB TEMPERATURES
Z (M) MEAN STDV
21.3 17.1 0.2
16.8 17.0 0.1
11.7 18.3 0.2
6.4 18.0 0.1
1.9 18.0 0.2
MEAN TEMPERATURE, (C)
16.70
17.10
17.50
17.90
18.30
18.70
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)


04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
DEW POINT TEMPERATURES
Z (M) MEAN STDV
21.3 13.6 0.3
16.8 13.4 0.3
11.7 15.7 0.2
6.4 14.7 0.2
1.9 14.6 0.2
MEAN TEMPERATURE, (C)
16.30
15.60
14.90
14.20
13.50
12.80
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

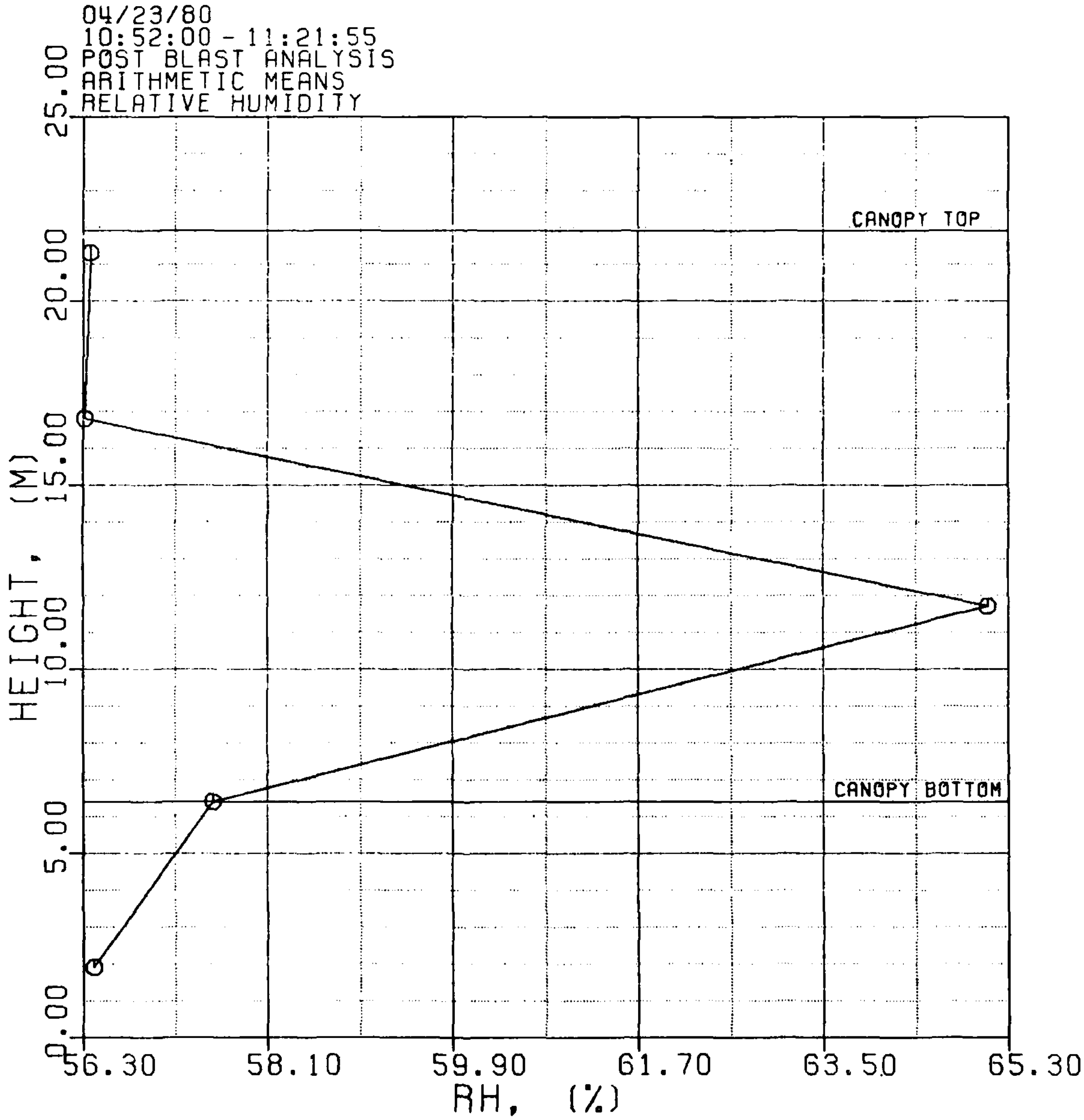

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
RELATIVE HUMIDITY
Z (M) MEAN STDV
21.3 56.4 1.5
16.8 56.3 2.5
11.7 65.1 1.5
6.4 57.6 1.8
1.9 56.4 2.0
RH, (%)
68.70
65.10
61.50
57.90
54.30
50.70
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

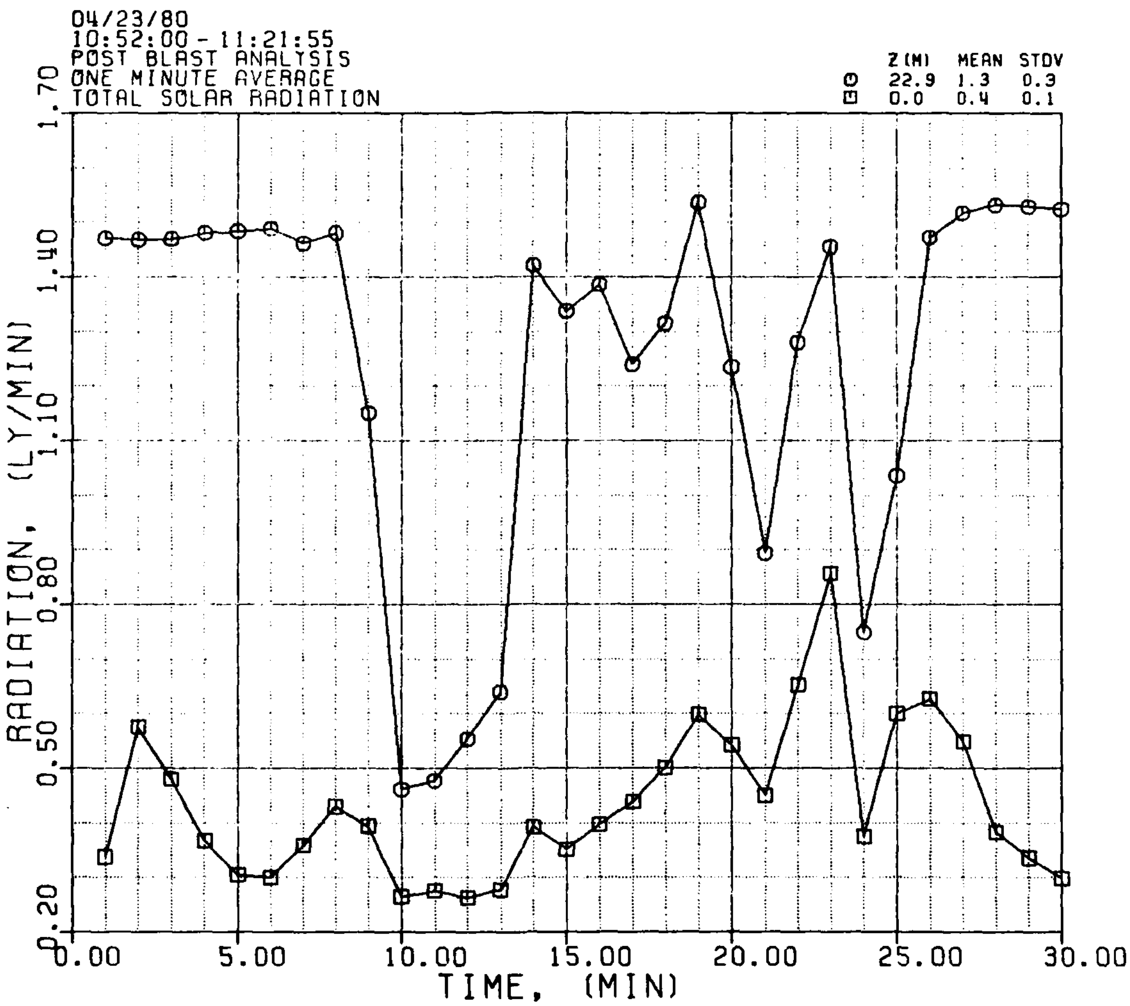

04/23/80
10:52:00 - 11:21:55
PØST BLAST ANALYSIS
ARITHMETIC MEANS
DRY BULB TEMPERATURES
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
22.60
22.90
23.20
23.50
23.80
24.10
MEAN TEMPERATURE, (C)


04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ARITHMETIC MEANS
WET BULB TEMPERATURES
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
16.90
17.20
17.50
17.80
18.10
18.40
MEAN TEMPERATURE, (C)



04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ARITHMETIC MEANS
DEW POINT TEMPERATURES
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
13.30
13.80
14.30
14.80
15.30
15.80
MEAN TEMPERATURE, (C)

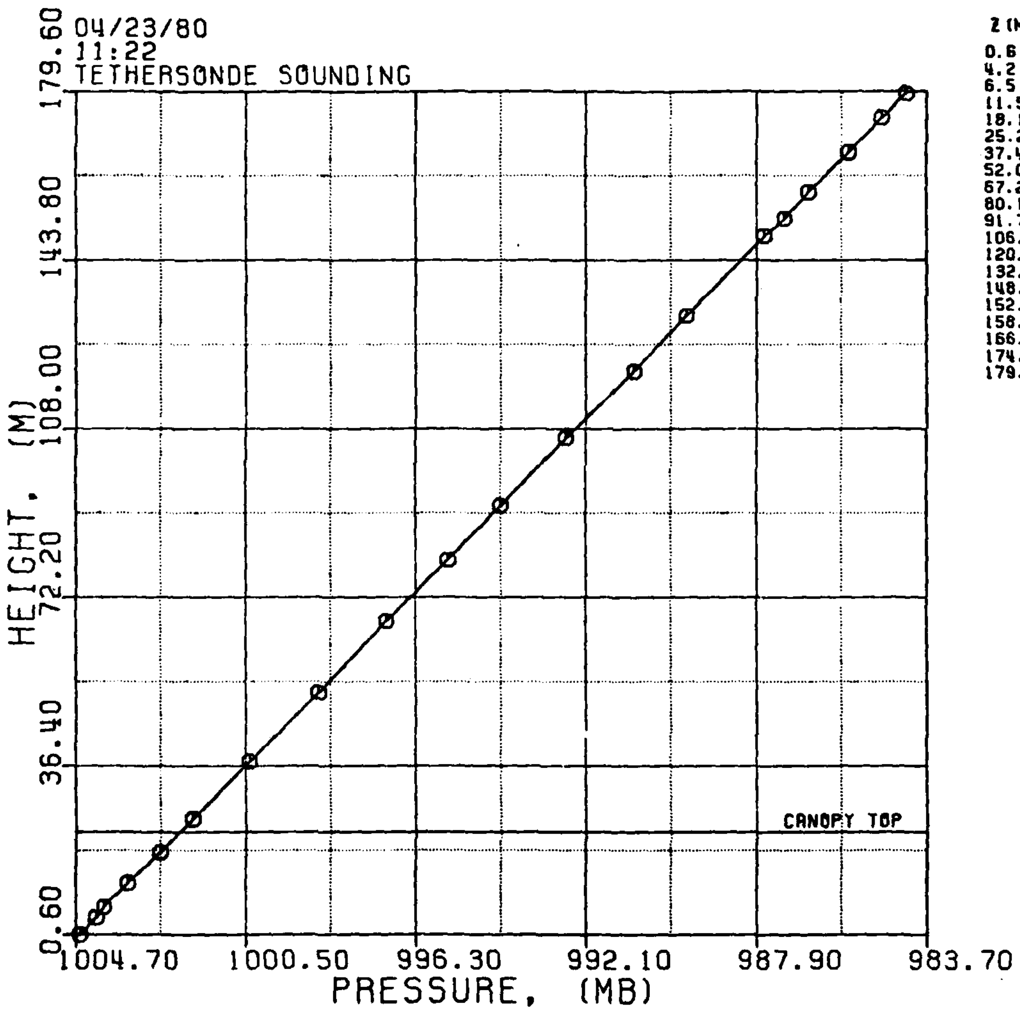

04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ARITHMETIC MEANS
RELATIVE HUMIDITY
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
56.30
58.10
59.90
61.70
63.50
65.30
RH, (%)


04/23/80
10:52:00 - 11:21:55
POST BLAST ANALYSIS
ONE MINUTE AVERAGE
TOTAL SOLAR RADIATION
Z(M) MEAN STDV
22.9 1.3 0.3
0.0 0.4 0.1
RADIATION, (LY/MIN)
0.20
0.50
0.80
1.10
1.40
1.70
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

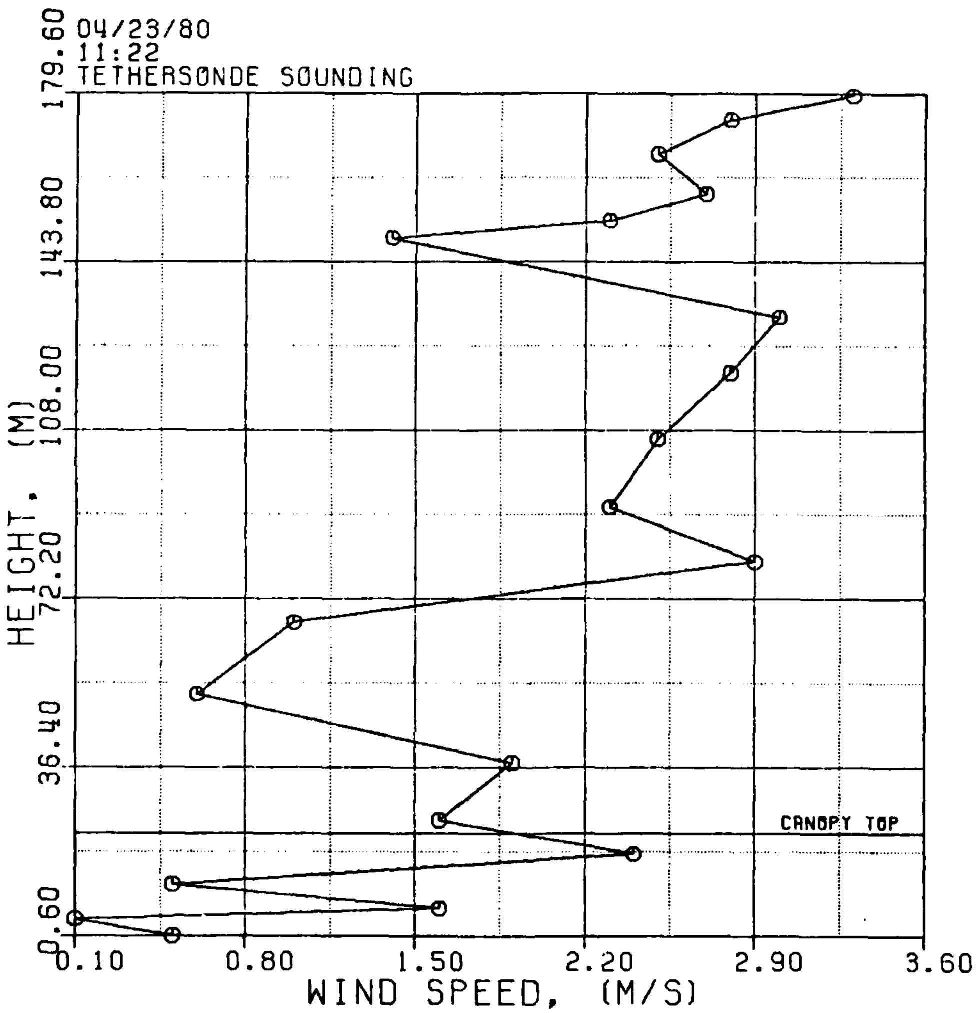
SUPPLEMENT II

SAMPLE OF A TETHERSONDE BALLOON SURVEY: FIGURES

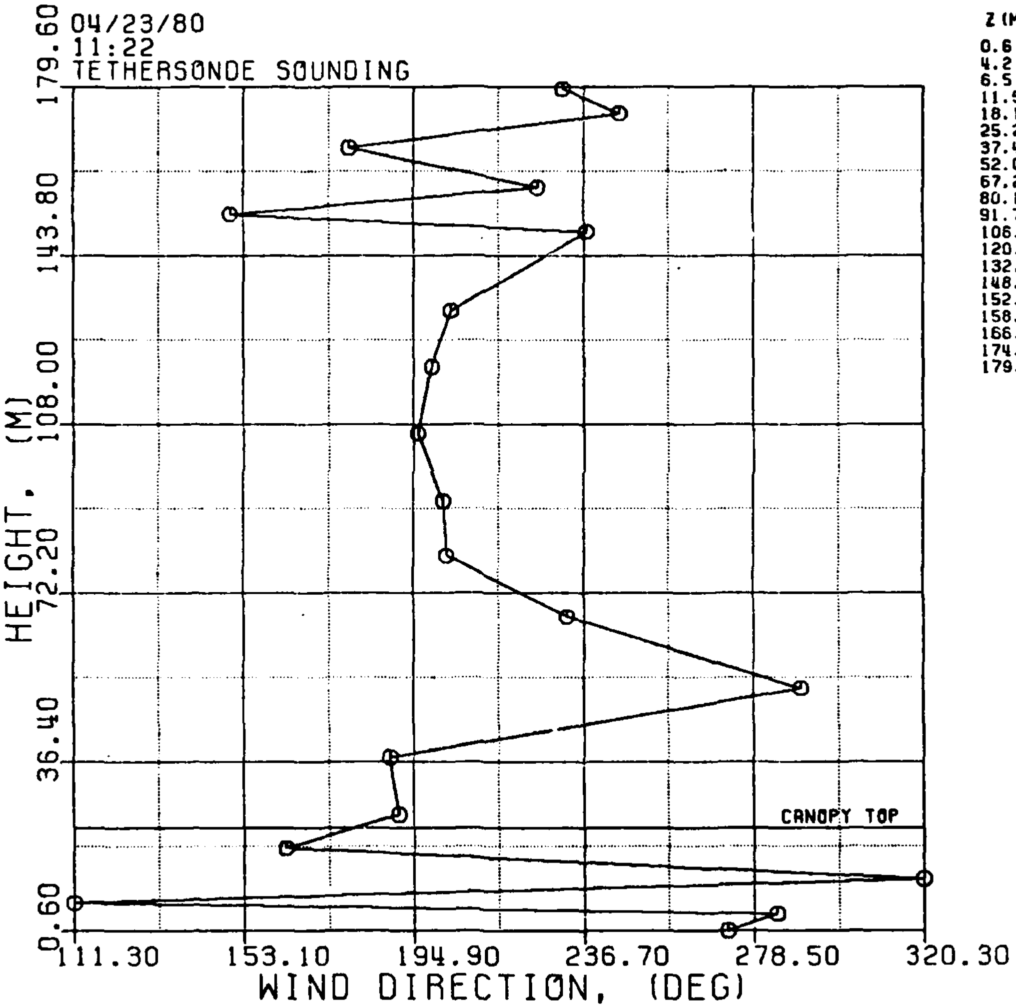
In this supplement, figures of the results for one tethersonde balloon sounding presented in Appendix V, Test Code 27-C9-AB, are given. The order in which these figures are shown is listed below.



Z (M)	TIME
0.6	11:22:35
4.2	11:23:17
6.5	11:23:59
11.5	11:24:41
18.1	11:25:24
25.2	11:26:06
37.4	11:26:49
52.0	11:27:31
67.2	11:28:13
80.1	11:28:55
91.7	11:29:37
106.1	11:30:19
120.2	11:31:01
132.1	11:31:44
148.9	11:32:26
152.6	11:33:08
158.2	11:33:50
166.7	11:34:32
174.0	11:35:14
179.2	11:35:56



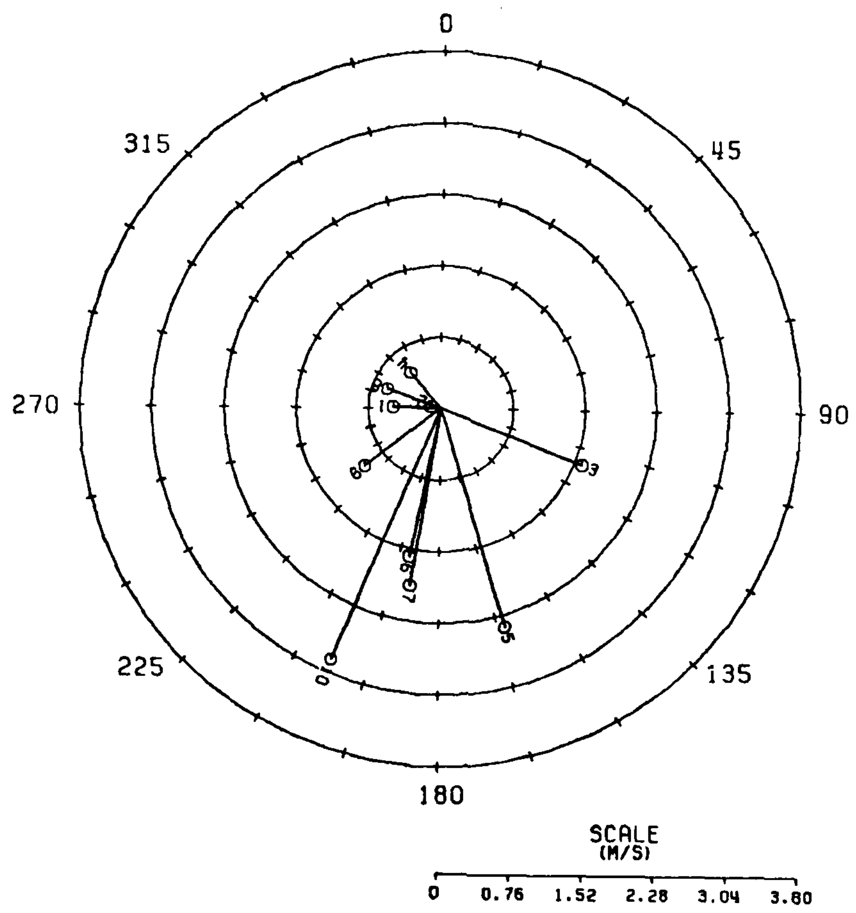
Z (M)	TIME
0.6	11:22:35
4.2	11:23:17
6.5	11:23:59
11.5	11:24:41
18.1	11:25:24
25.2	11:26:06
37.4	11:26:49
52.0	11:27:31
67.2	11:28:13
80.1	11:28:55
91.7	11:29:37
106.1	11:30:19
120.2	11:31:01
132.1	11:31:44
148.9	11:32:26
152.6	11:33:08
158.2	11:33:50
166.7	11:34:32
174.0	11:35:14
179.2	11:35:56



Z (M)	TIME
0.6	11:22:35
4.2	11:23:17
6.5	11:23:59
11.5	11:24:41
18.1	11:25:24
25.2	11:26:06
37.4	11:26:49
52.0	11:27:31
67.2	11:28:13
80.1	11:28:55
91.7	11:29:37
106.1	11:30:19
120.2	11:31:01
132.1	11:31:44
148.9	11:32:26
152.6	11:33:08
158.2	11:33:50
166.7	11:34:32
174.0	11:35:14
179.2	11:35:56

04/23/80
11:22
TETHERSONDE SOUNDING

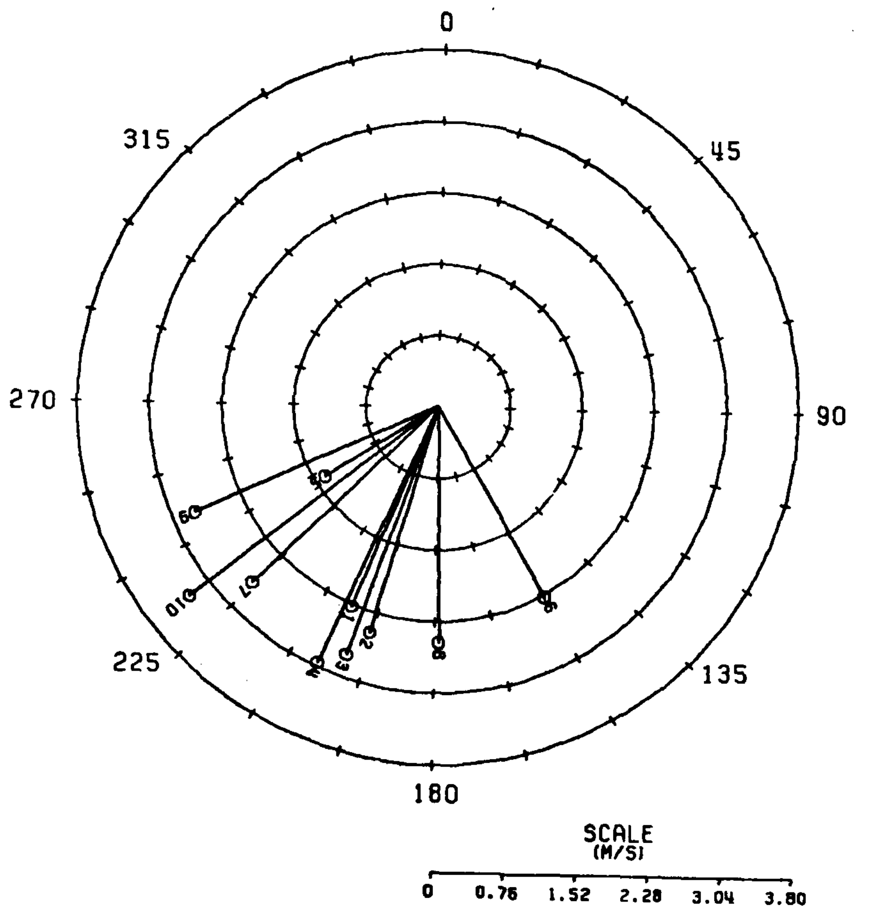
WIND VECTORS W/ HEIGHT



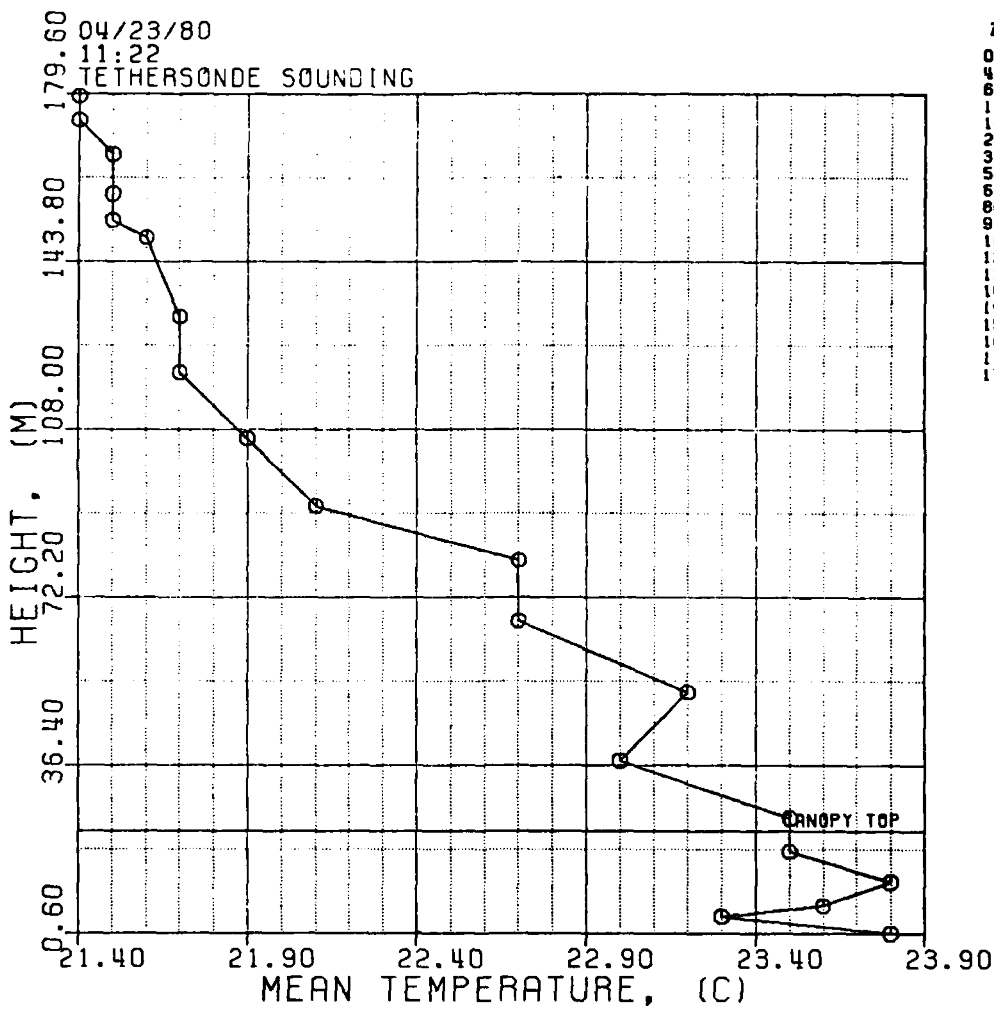
	Z (M)	TIME
1	0.6	11:22:35
2	4.2	11:23:17
3	6.5	11:23:59
4	11.5	11:24:41
5	18.1	11:25:24
6	25.2	11:26:06
7	37.4	11:26:49
8	52.0	11:27:31
9	67.2	11:28:13
10	80.1	11:28:55

04/23/80
11:22
TETHERSONDE SOUNDING

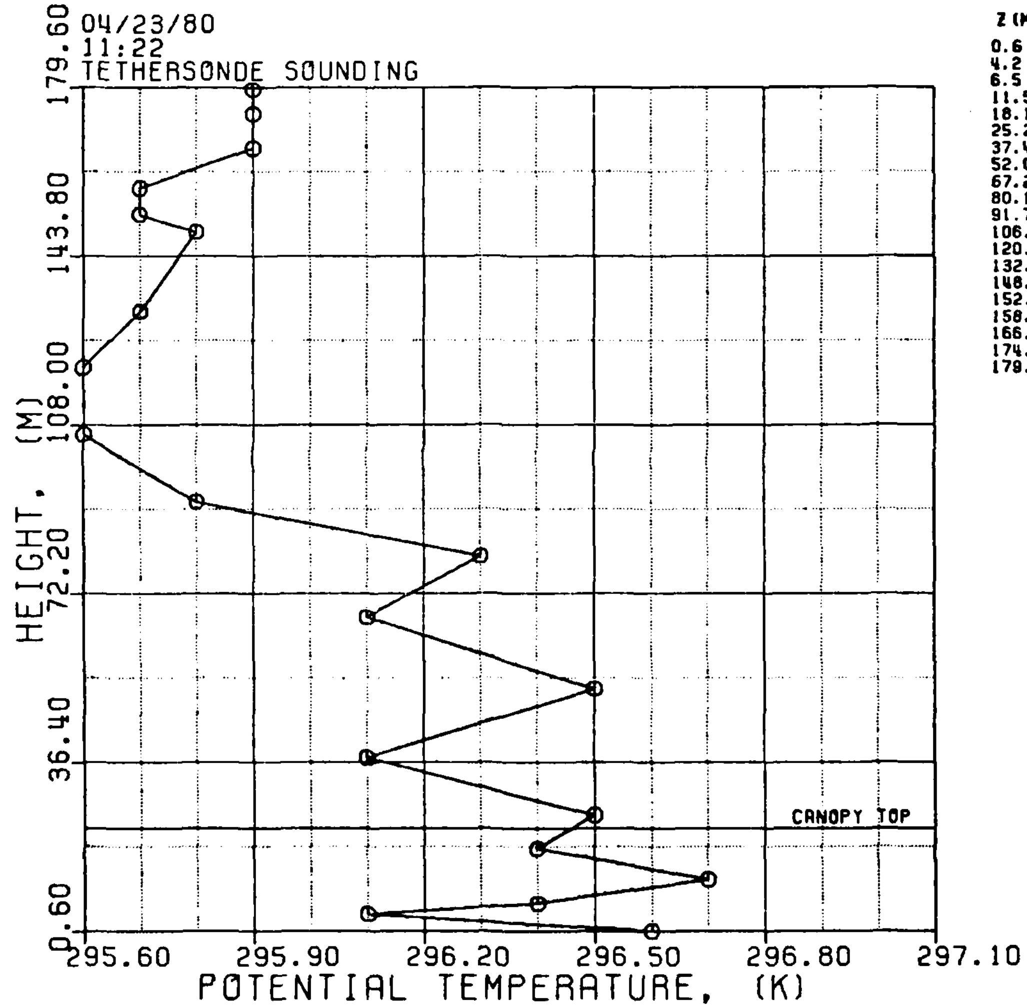
WIND VECTORS W/ HEIGHT



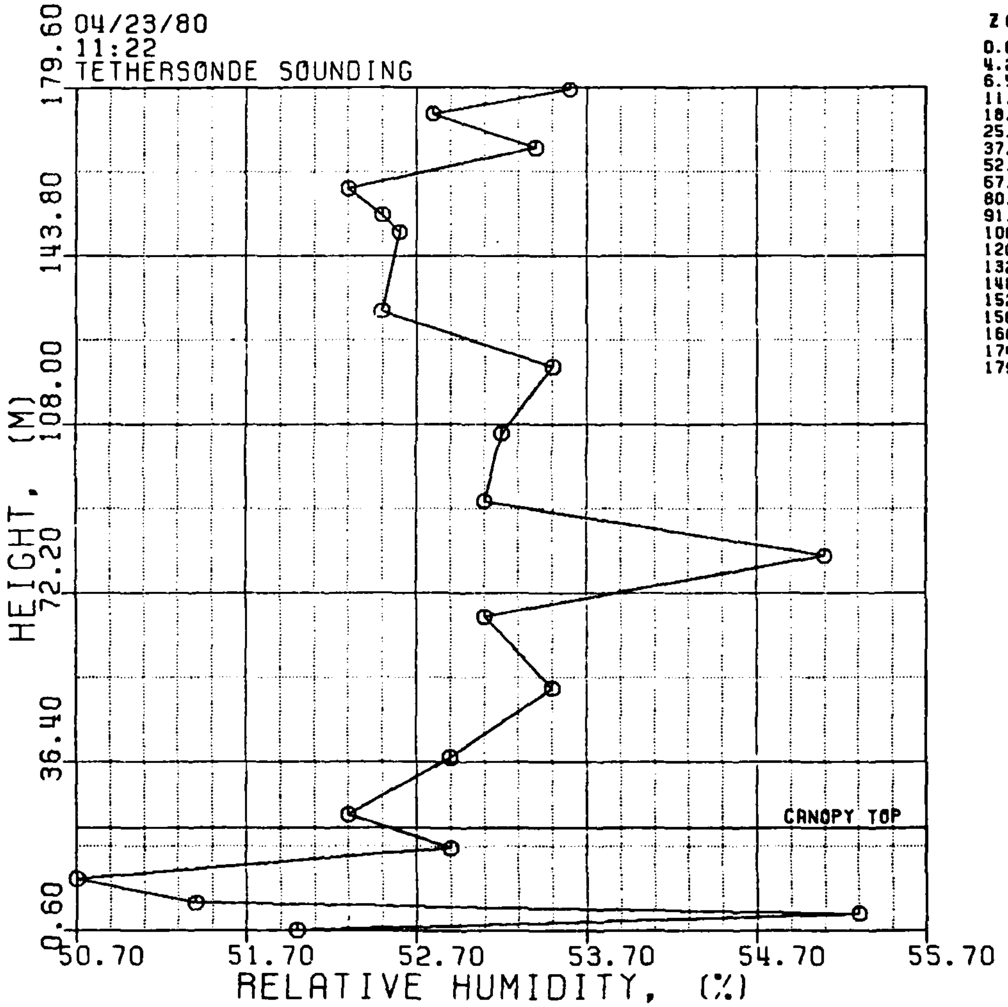
	Z (M)	TIME
1	91.7	11:29:37
2	106.1	11:30:19
3	120.2	11:31:01
4	132.1	11:31:44
5	148.9	11:32:26
6	152.6	11:33:08
7	158.2	11:33:50
8	166.7	11:34:32
9	174.0	11:35:14
10	179.2	11:35:56



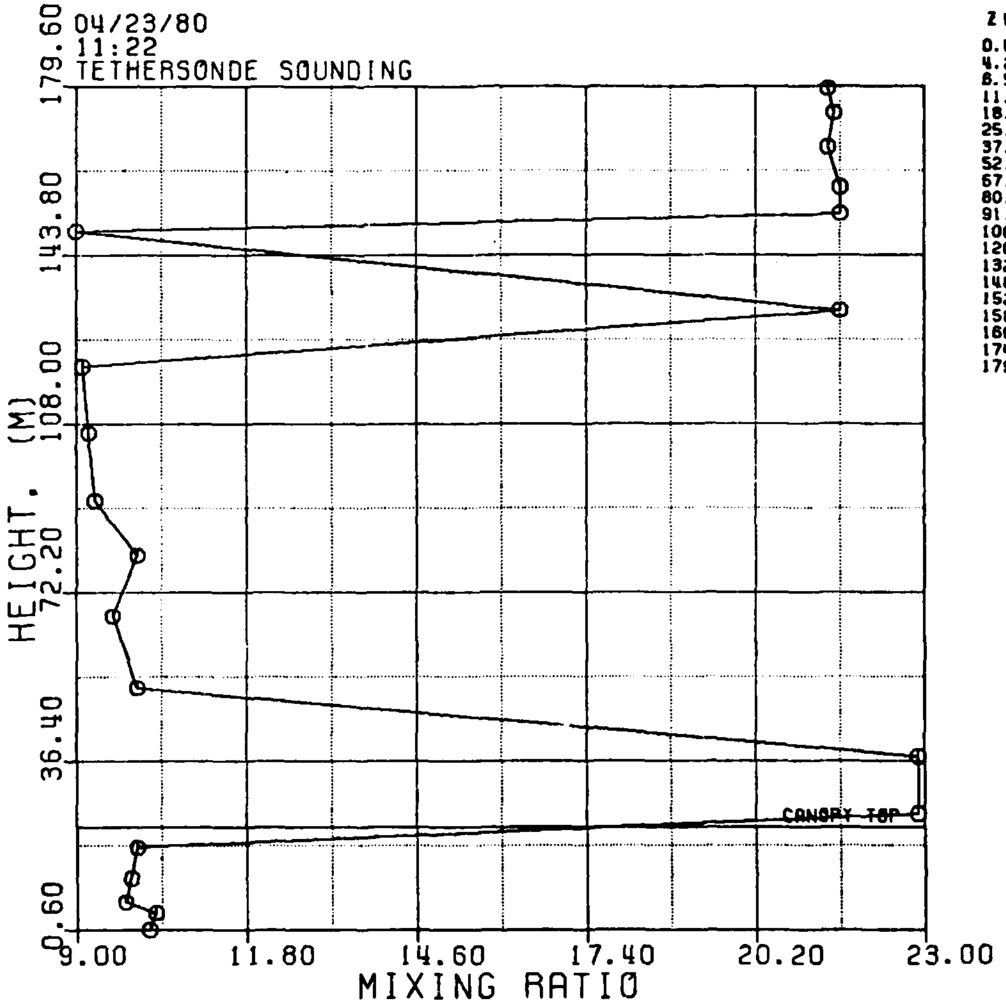
Z (M)	TIME
0.6	11:22:35
4.2	11:23:17
6.5	11:23:59
11.5	11:24:41
18.1	11:25:24
25.2	11:26:06
37.4	11:26:49
52.0	11:27:31
67.2	11:28:13
80.1	11:28:55
91.7	11:29:37
106.1	11:30:19
120.2	11:31:01
132.1	11:31:44
148.9	11:32:26
152.6	11:33:08
158.2	11:33:50
166.7	11:34:32
174.0	11:35:14
179.2	11:35:56



Z (M)	TIME
0.6	11:22:35
4.2	11:23:17
6.5	11:23:59
11.5	11:24:41
18.1	11:25:24
25.2	11:26:06
37.4	11:26:49
52.0	11:27:31
67.2	11:28:13
80.1	11:28:55
91.7	11:29:37
106.1	11:30:19
120.2	11:31:01
132.1	11:31:44
148.9	11:32:26
152.6	11:33:08
158.2	11:33:50
166.7	11:34:32
174.0	11:35:14
179.2	11:35:56



Z (M)	TIME
0.8	11:22:35
4.2	11:23:17
6.5	11:23:59
11.5	11:24:41
18.1	11:25:24
25.2	11:26:06
37.4	11:26:49
52.0	11:27:31
67.2	11:28:13
80.1	11:28:55
91.7	11:29:37
106.1	11:30:19
120.2	11:31:01
132.1	11:31:44
148.9	11:32:26
152.6	11:33:08
158.2	11:33:50
166.7	11:34:32
174.0	11:35:14
179.2	11:35:56

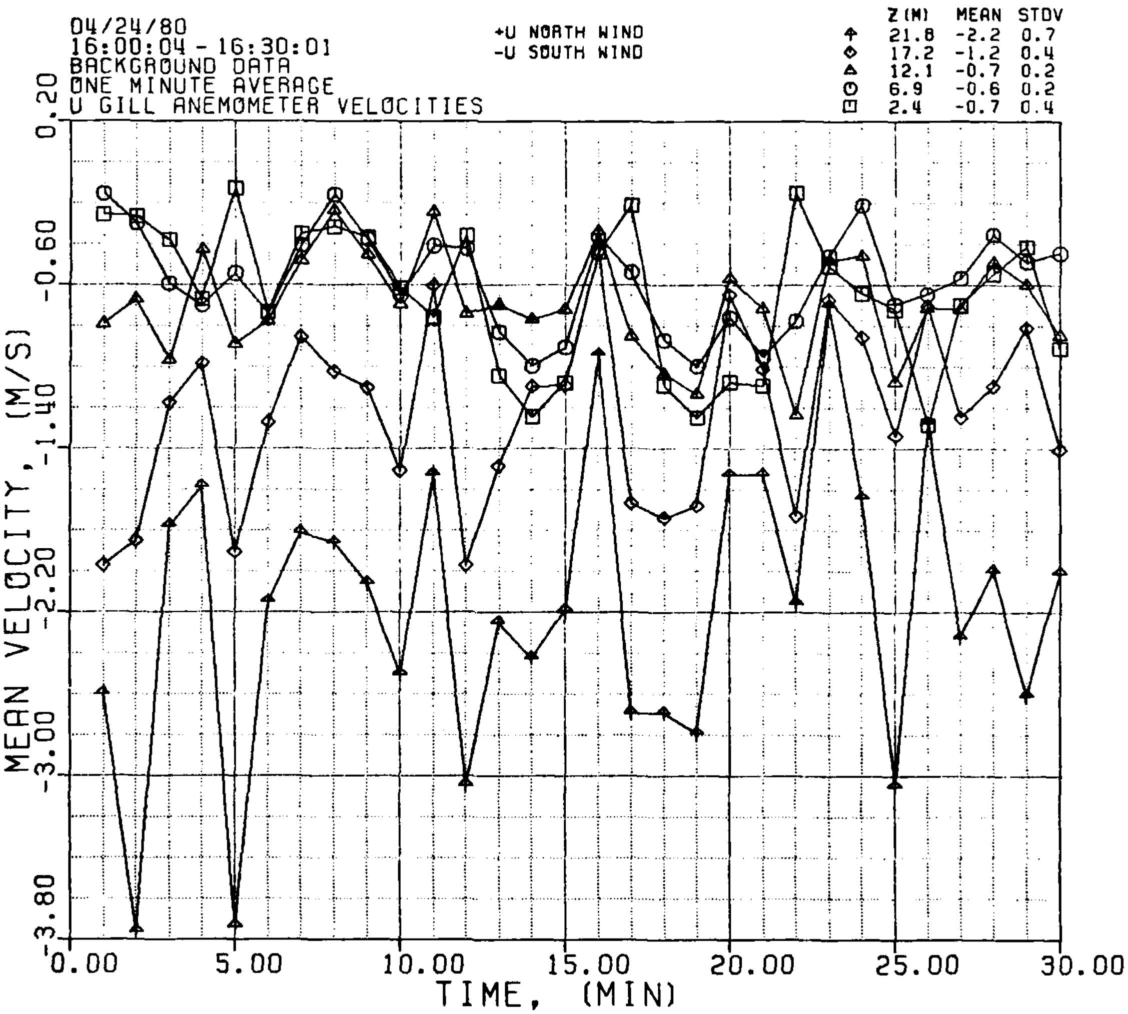


Z (M)	TIME
0.6	11:22:35
4.2	11:29:17
8.5	11:23:59
11.5	11:24:41
18.1	11:25:24
25.2	11:26:06
37.4	11:26:49
52.0	11:27:31
67.2	11:28:13
80.1	11:28:55
91.7	11:29:37
106.1	11:30:19
120.2	11:31:01
132.1	11:31:44
148.9	11:32:26
152.6	11:33:08
158.2	11:33:50
166.7	11:34:32
174.0	11:35:14
179.2	11:35:56

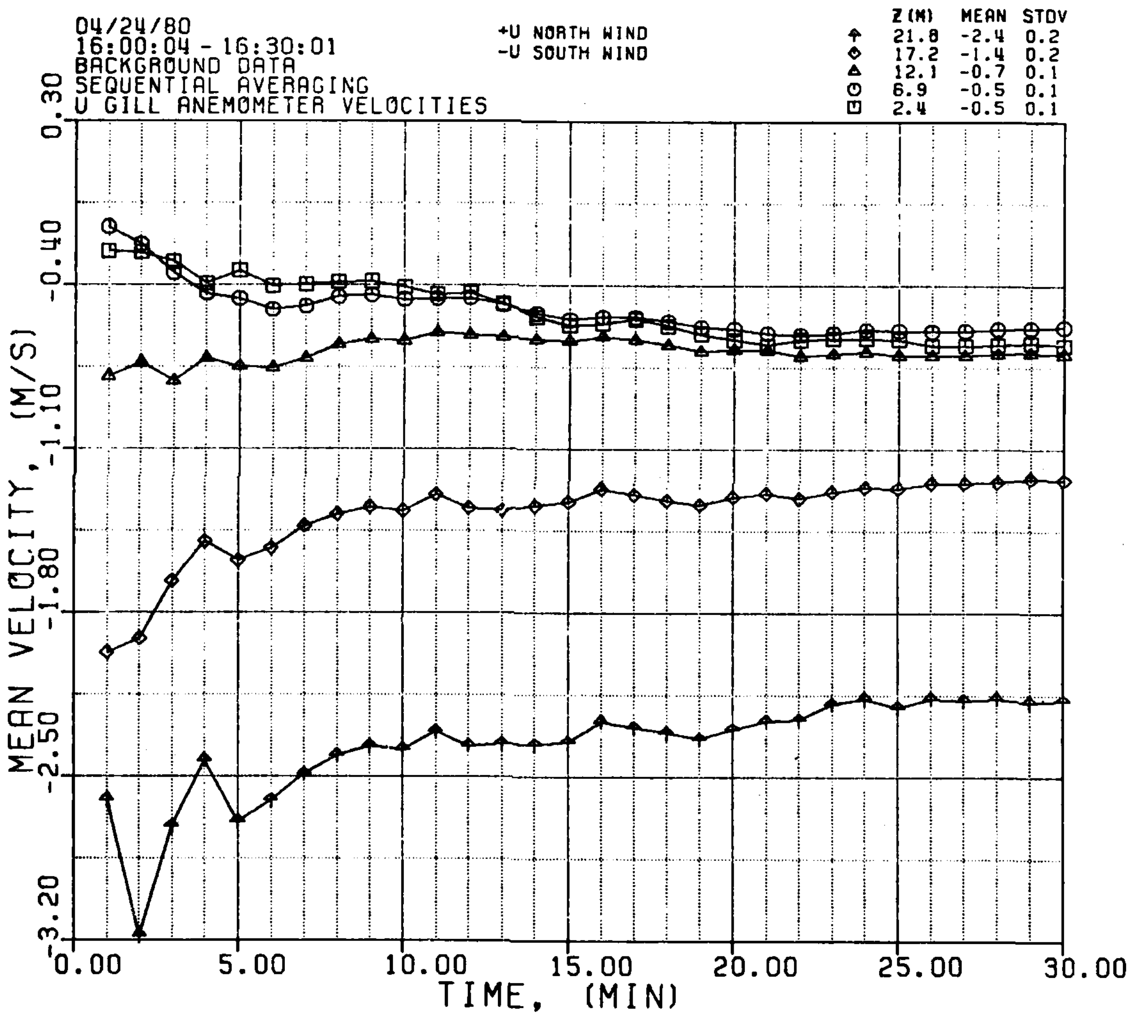
SUPPLEMENT III

SAMPLE OF A BACKGROUND METEOROLOGICAL DATA SAMPLE PERIOD: FIGURES

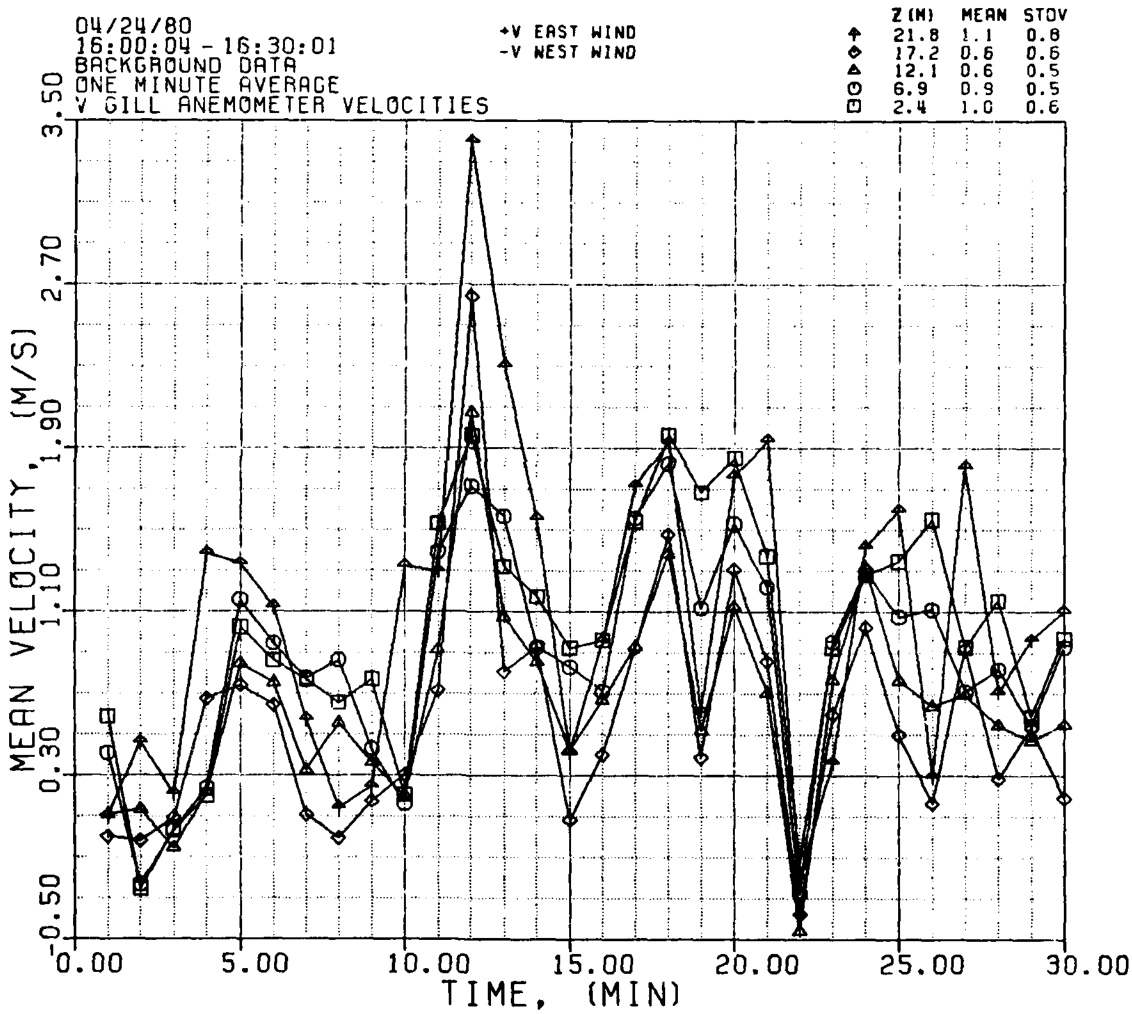
In this supplement, figures of the results for one background meteorological data sample period presented in Appendix VII, Test Code BMD-24-6, are given. The order in which these figures are shown is listed below.

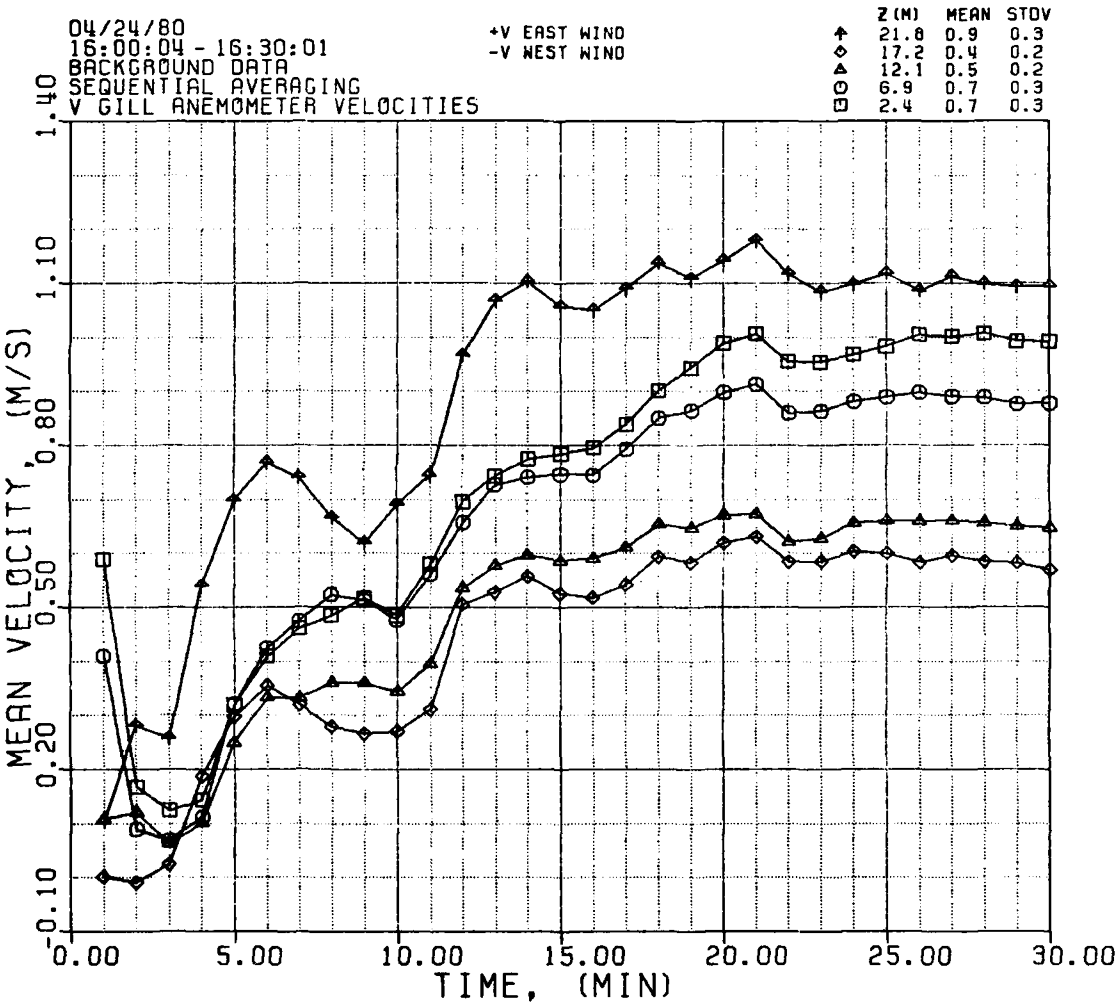


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
U GILL ANEMOMETER VELOCITIES
+U NORTH WIND
-U SOUTH WIND
Z (M) MEAN STDV
21.8 -2.2 0.7
17.2 -1.2 0.4
12.1 -0.7 0.2
6.9 -0.6 0.2
2.4 -0.7 0.4
MEAN VELOCITY, (M/S)
0.20
-0.60
-1.40
-2.20
-3.00
-3.80
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

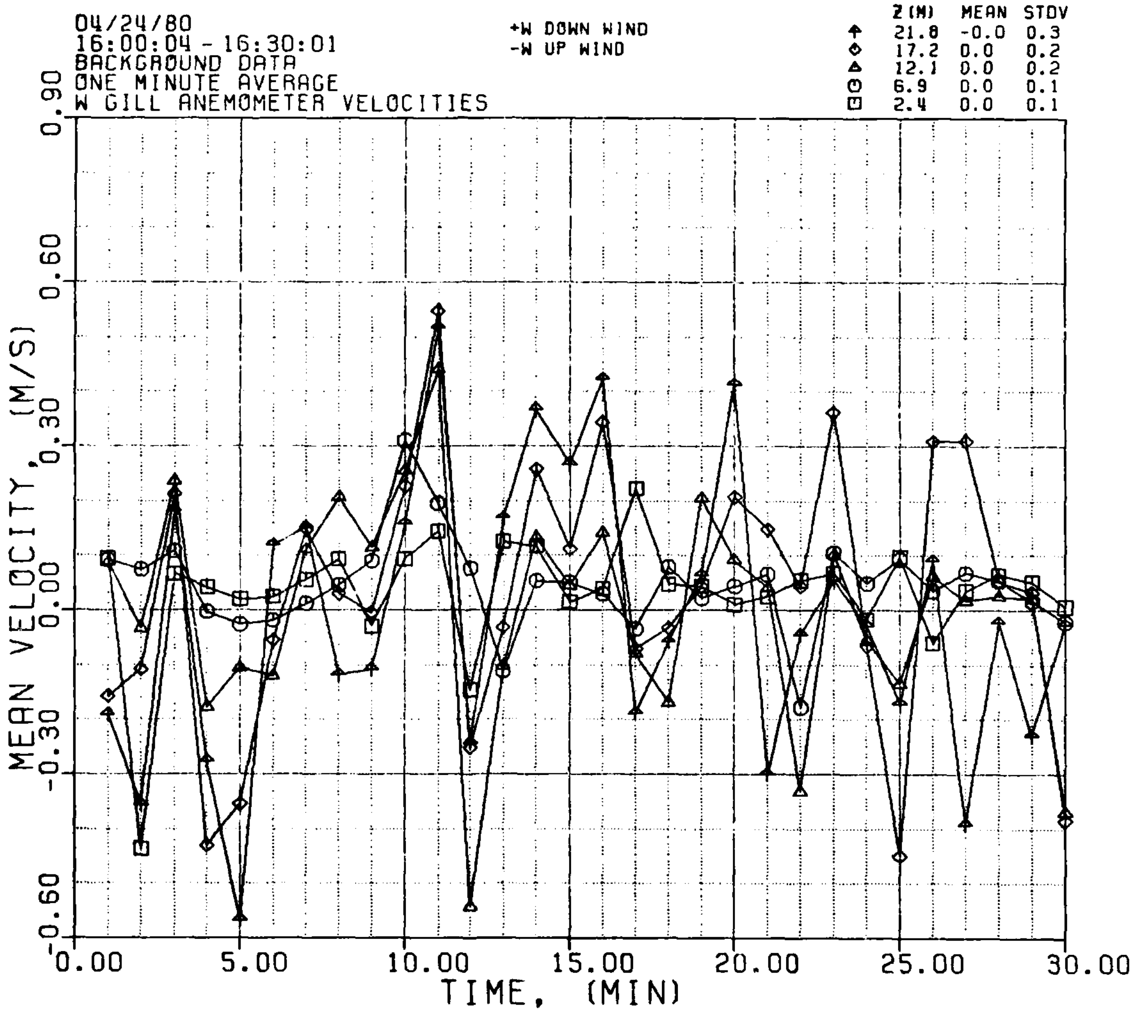


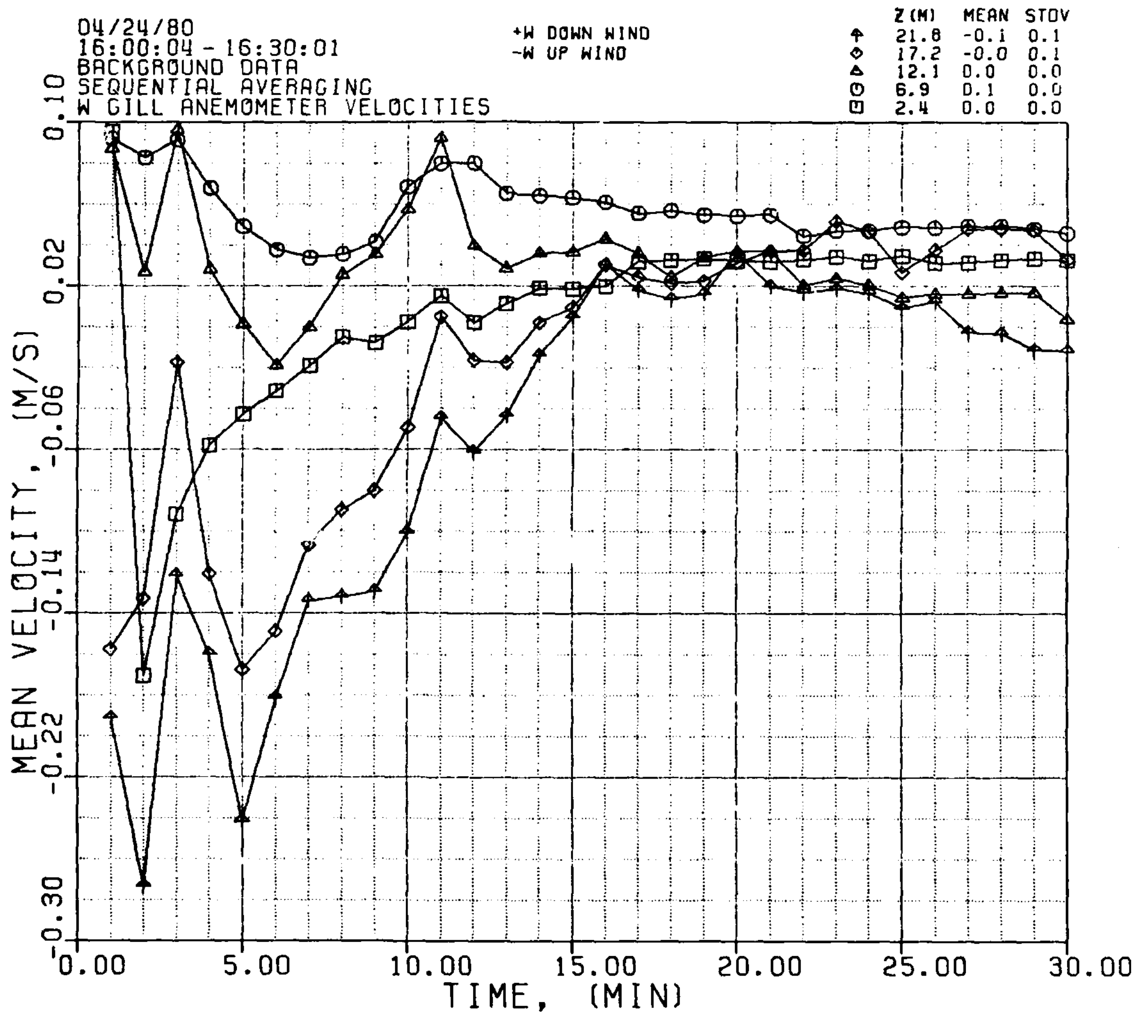
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
SEQUENTIAL AVERAGING
U GILL ANEMOMETER VELOCITIES
+U NORTH WIND
-U SOUTH WIND
Z (M) MEAN STDV
21.8 -2.4 0.2
17.2 -1.4 0.2
12.1 -0.7 0.1
6.9 -0.5 0.1
2.4 -0.5 0.1
MEAN VELOCITY, (M/S)
0.30
-0.40
-1.10
-1.80
-2.50
-3.20
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

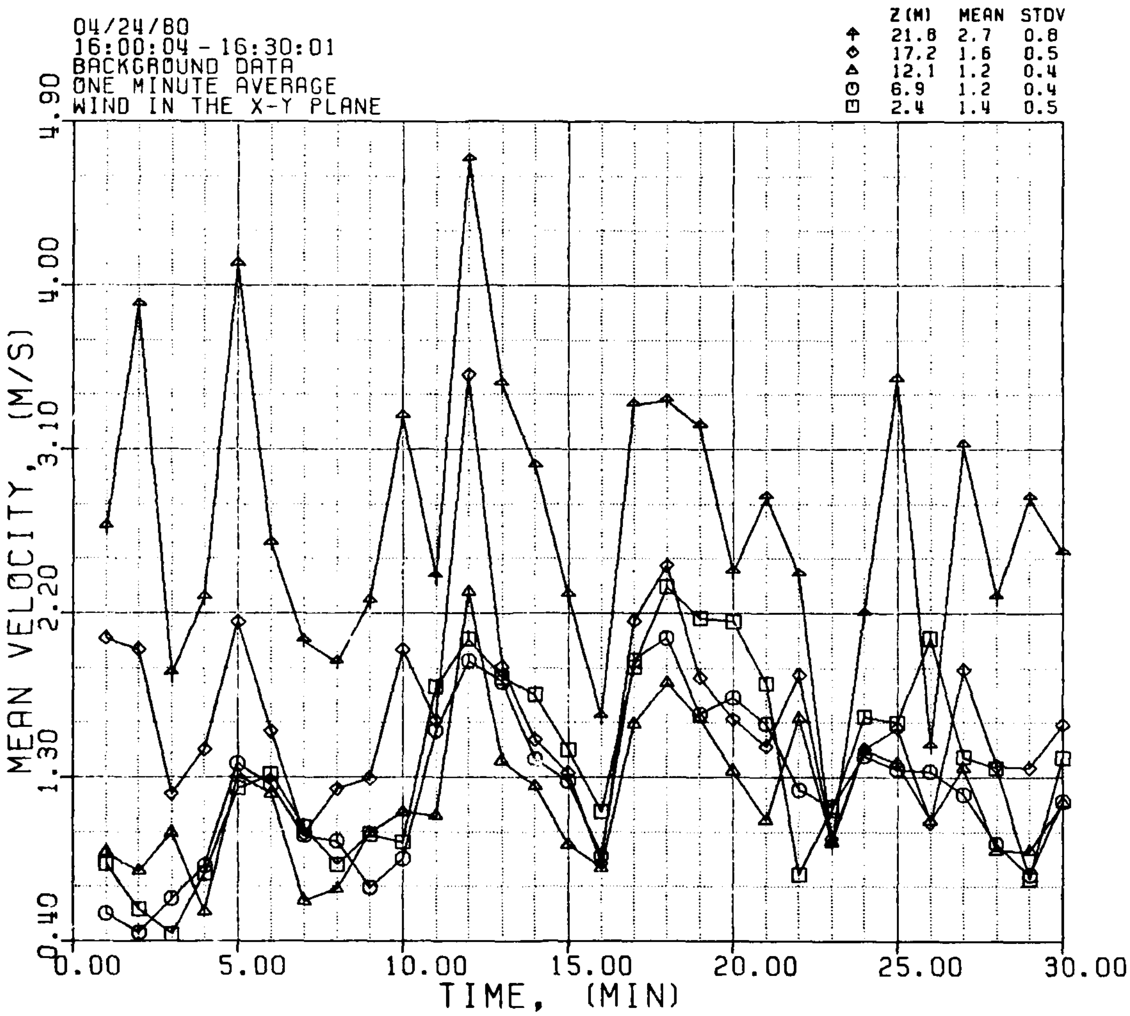

04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
V GILL ANEMOMETER VELOCITIES
+V EAST WIND
-V WEST WIND
Z(M) MEAN STDV
21.8 1.1 0.8
17.2 0.6 0.6
12.1 0.6 0.5
6.9 0.9 0.5
2.4 1.0 0.6
MEAN VELOCITY, (M/S)
-0.50
0.30
1.10
1.90
2.70
3.50
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

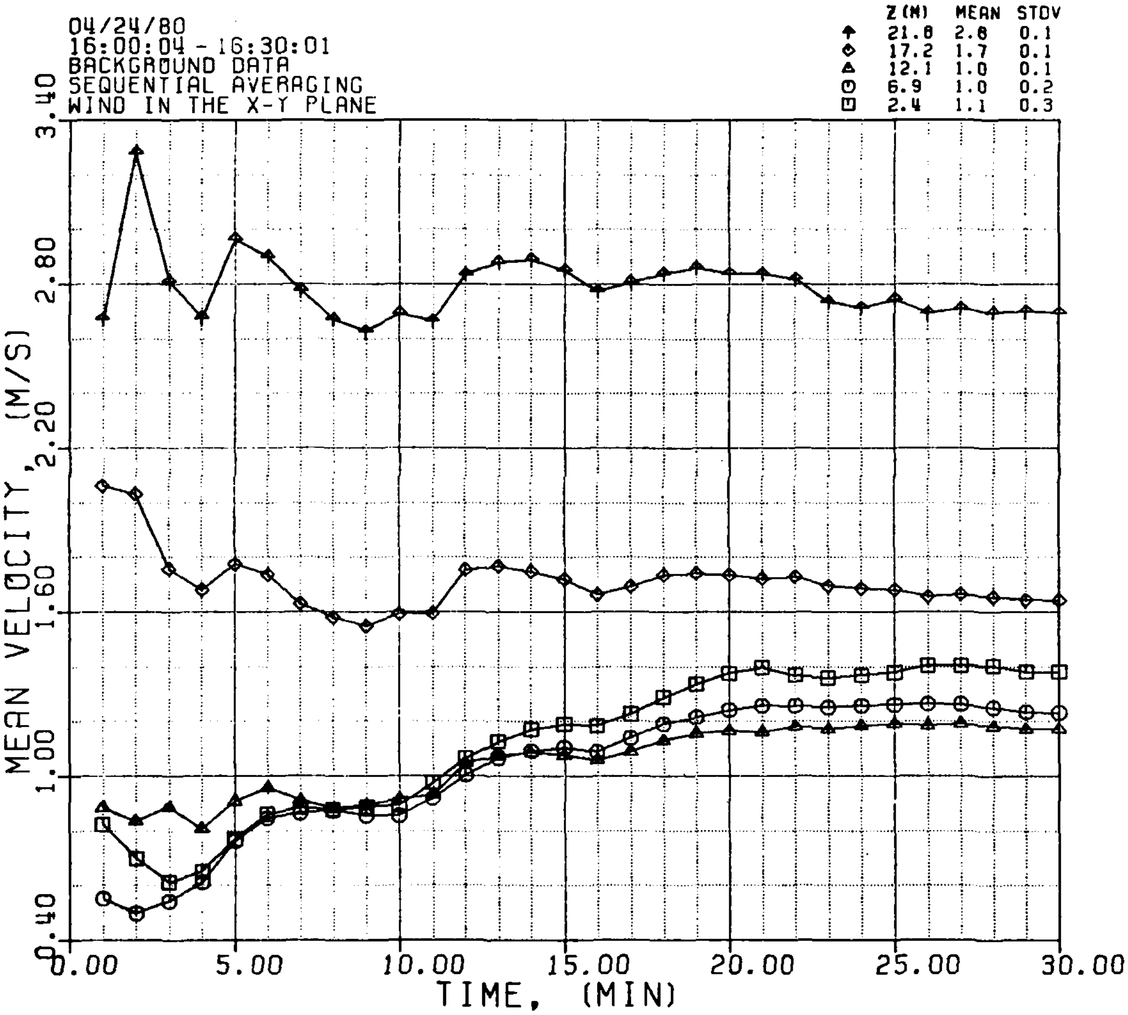


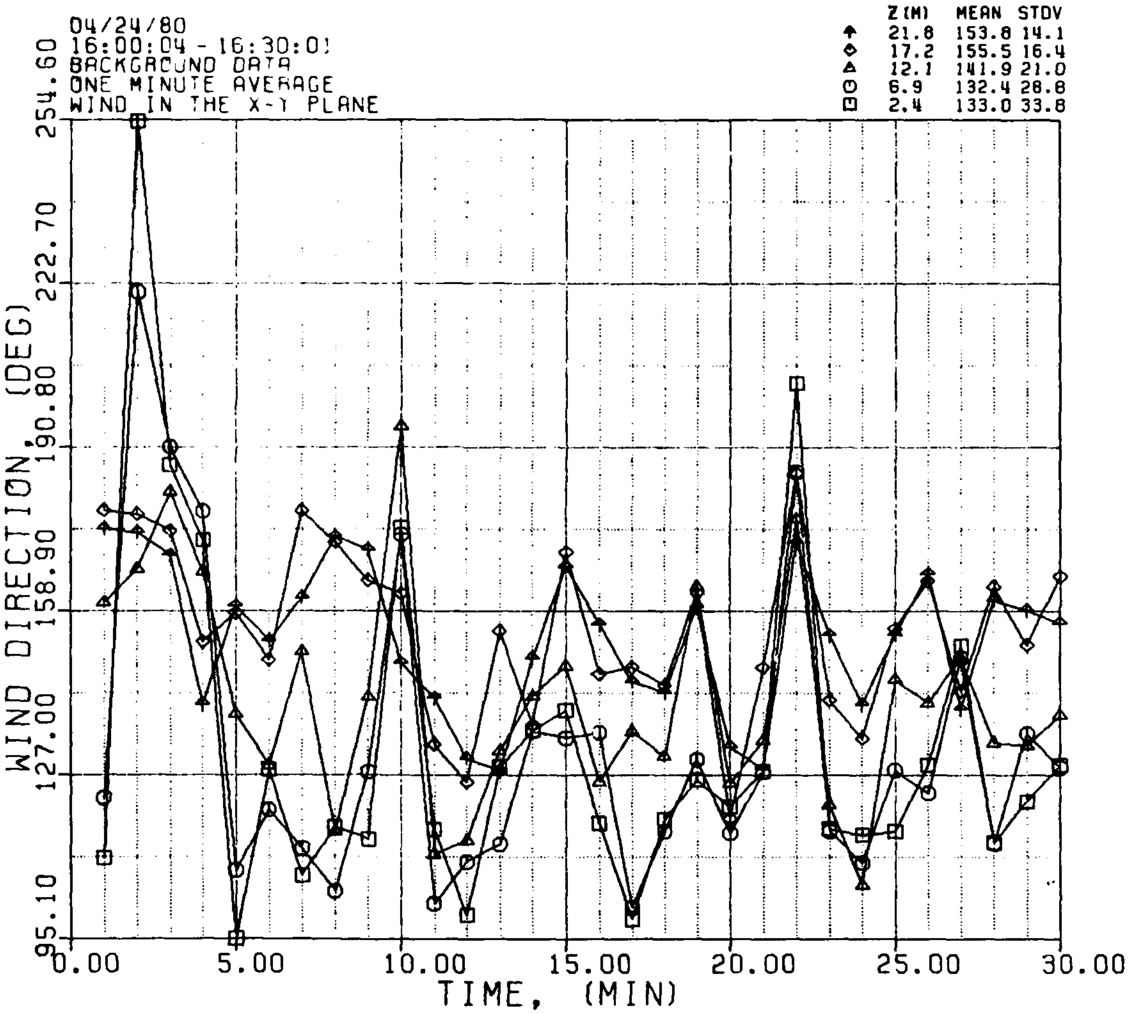
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
SEQUENTIAL AVERAGING
V GILL ANEMOMETER VELOCITIES
+V EAST WIND
-V WEST WIND
Z (M) MEAN STDV
21.8 0.9 0.3
17.2 0.4 0.2
12.1 0.5 0.2
6.9 0.7 0.3
2.4 0.7 0.3
MEAN VELOCITY, (M/S)
-0.10
0.20
0.50
0.80
1.10
1.40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
W GILL ANEMOMETER VELOCITIES
+W DOWN WIND
-W UP WIND
Z (M) MEAN STDV
21.8 -0.0 0.3
17.2 0.0 0.2
12.1 0.0 0.2
6.9 0.0 0.1
2.4 0.0 0.1
MEAN VELOCITY, (M/S)
TIME, (MIN)
0.90
0.60
0.30
0.00
-0.30
-0.60
0.00
5.00
10.00
15.00
20.00
25.00
30.00

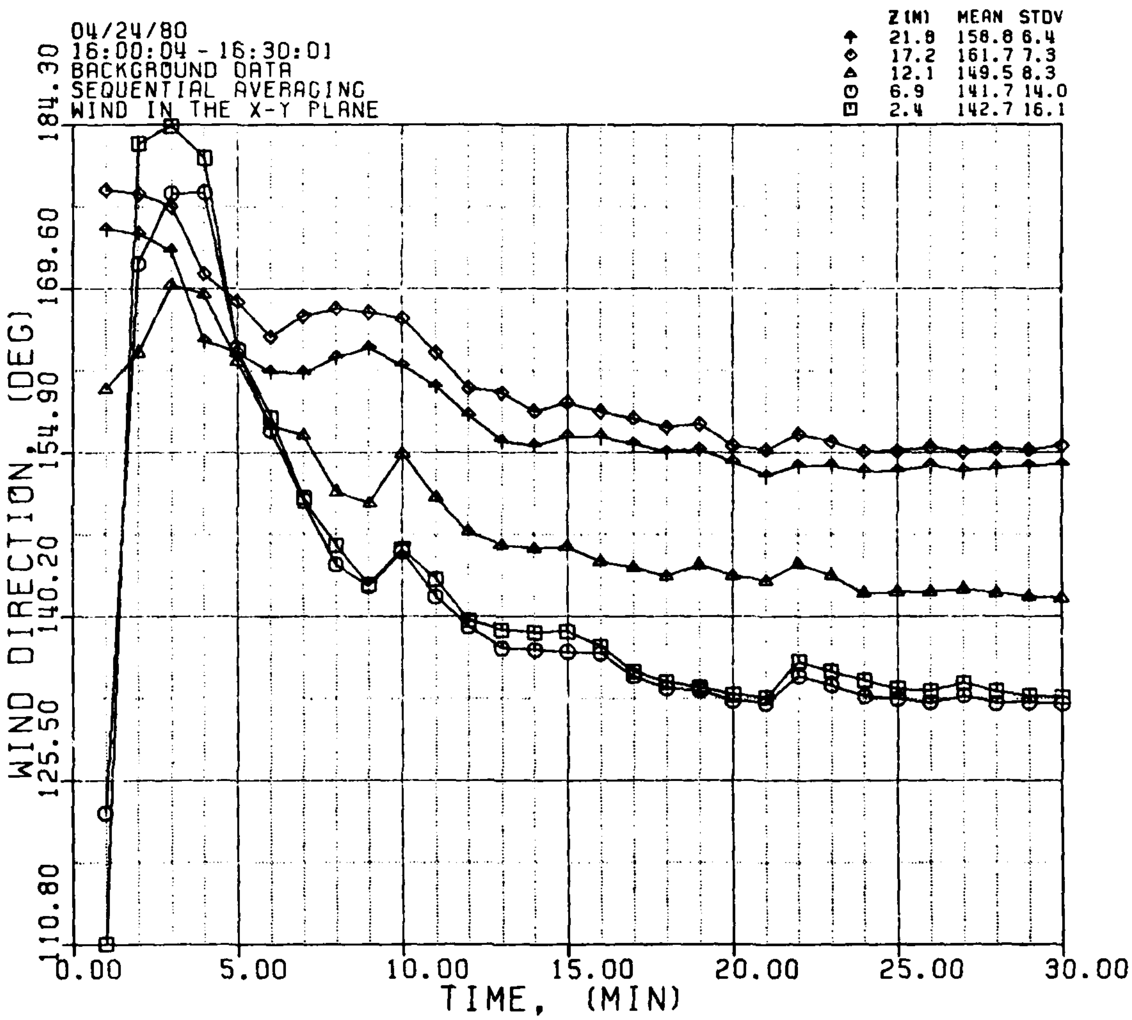

04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
SEQUENTIAL AVERAGING
W GILL ANEMOMETER VELOCITIES
+W DOWN WIND
-W UP WIND
Z(M) MEAN STDV
21.8 -0.1 0.1
17.2 -0.0 0.1
12.1 0.0 0.0
6.9 0.1 0.0
2.4 0.0 0.0
0.10
0.02
-0.06
-0.14
-0.22
-0.30
MEAN VELOCITY, (M/S)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

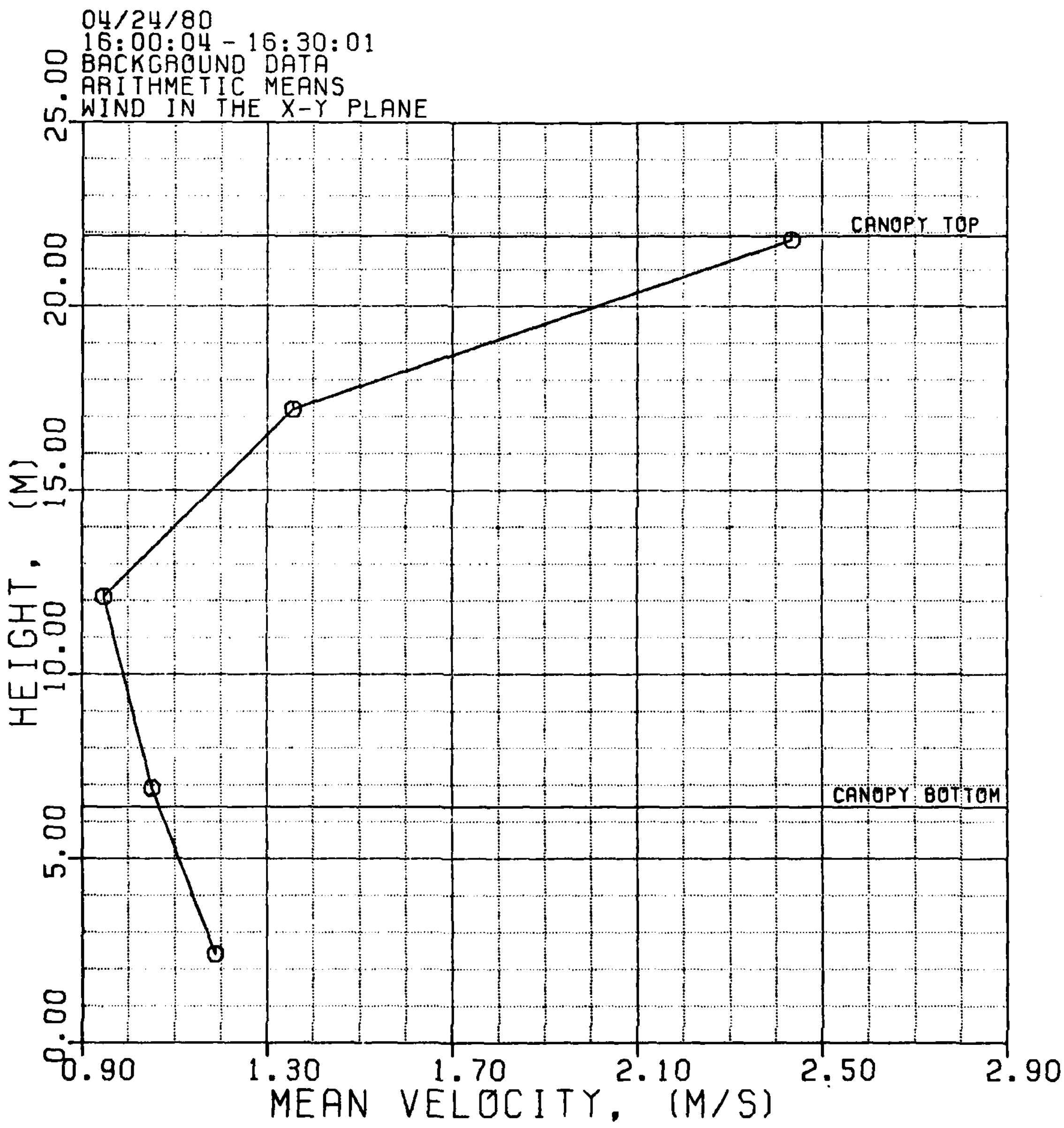

04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
WIND IN THE X-Y PLANE
Z(M) MEAN STDV
21.8 2.7 0.8
17.2 1.6 0.5
12.1 1.2 0.4
6.9 1.2 0.4
2.4 1.4 0.5
MEAN VELOCITY, (M/S)
0.40
1.30
2.20
3.10
4.00
4.90
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
SEQUENTIAL AVERAGING
WIND IN THE X-Y PLANE
Z (M) MEAN STDV
21.8 2.8 0.1
17.2 1.7 0.1
12.1 1.0 0.1
6.9 1.0 0.2
2.4 1.1 0.3
MEAN VELOCITY, (M/S)
0.40
1.00
1.60
2.20
2.80
3.40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

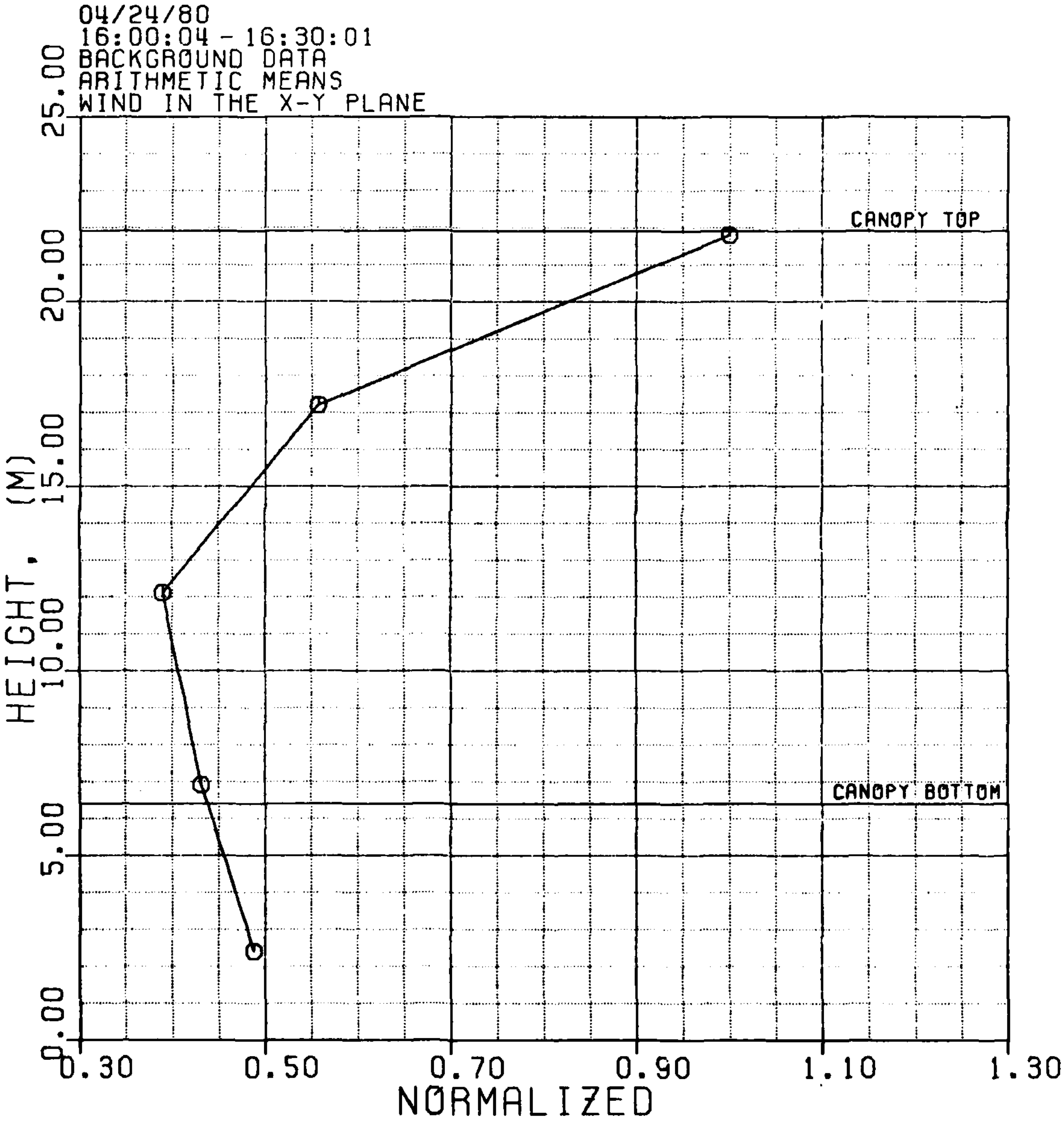


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
WIND IN THE X-Y PLANE
Z(M) MEAN STDV
21.8 153.8 14.1
17.2 155.5 16.4
12.1 141.9 21.0
6.9 132.4 28.8
2.4 133.0 33.8
WIND DIRECTION, (DEG)
254.60
222.70
190.80
158.90
127.00
95.10
TIME, (MIN)
0.00
5.00
10.00
15.00
20.00
25.00
30.00

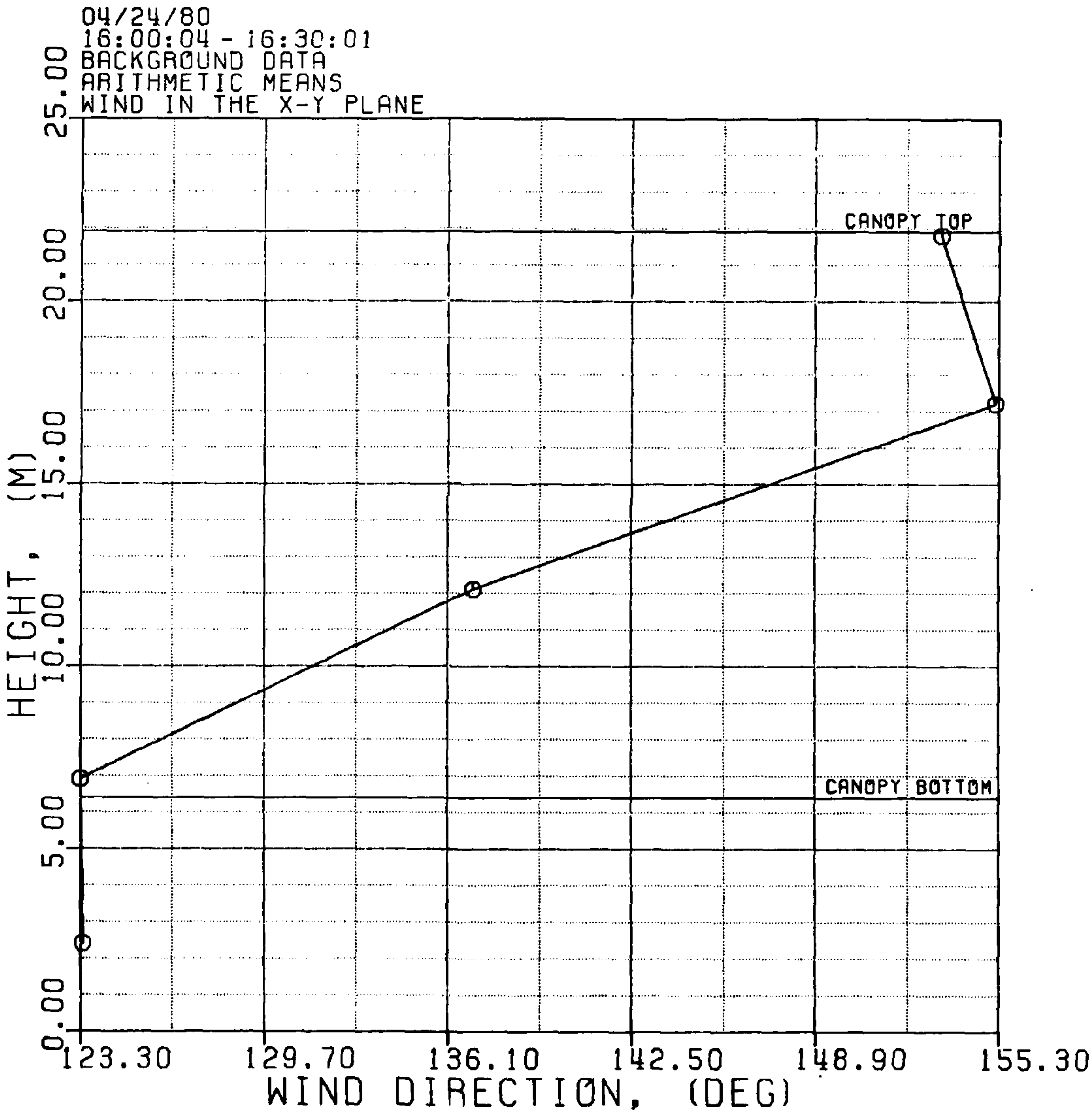

04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
SEQUENTIAL AVERAGING
WIND IN THE X-Y PLANE
Z(M) MEAN STDV
21.8 158.8 6.4
17.2 161.7 7.3
12.1 149.5 8.3
6.9 141.7 14.0
2.4 142.7 16.1
WIND DIRECTION, (DEG)
184.30
169.60
154.90
140.20
125.50
110.80
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

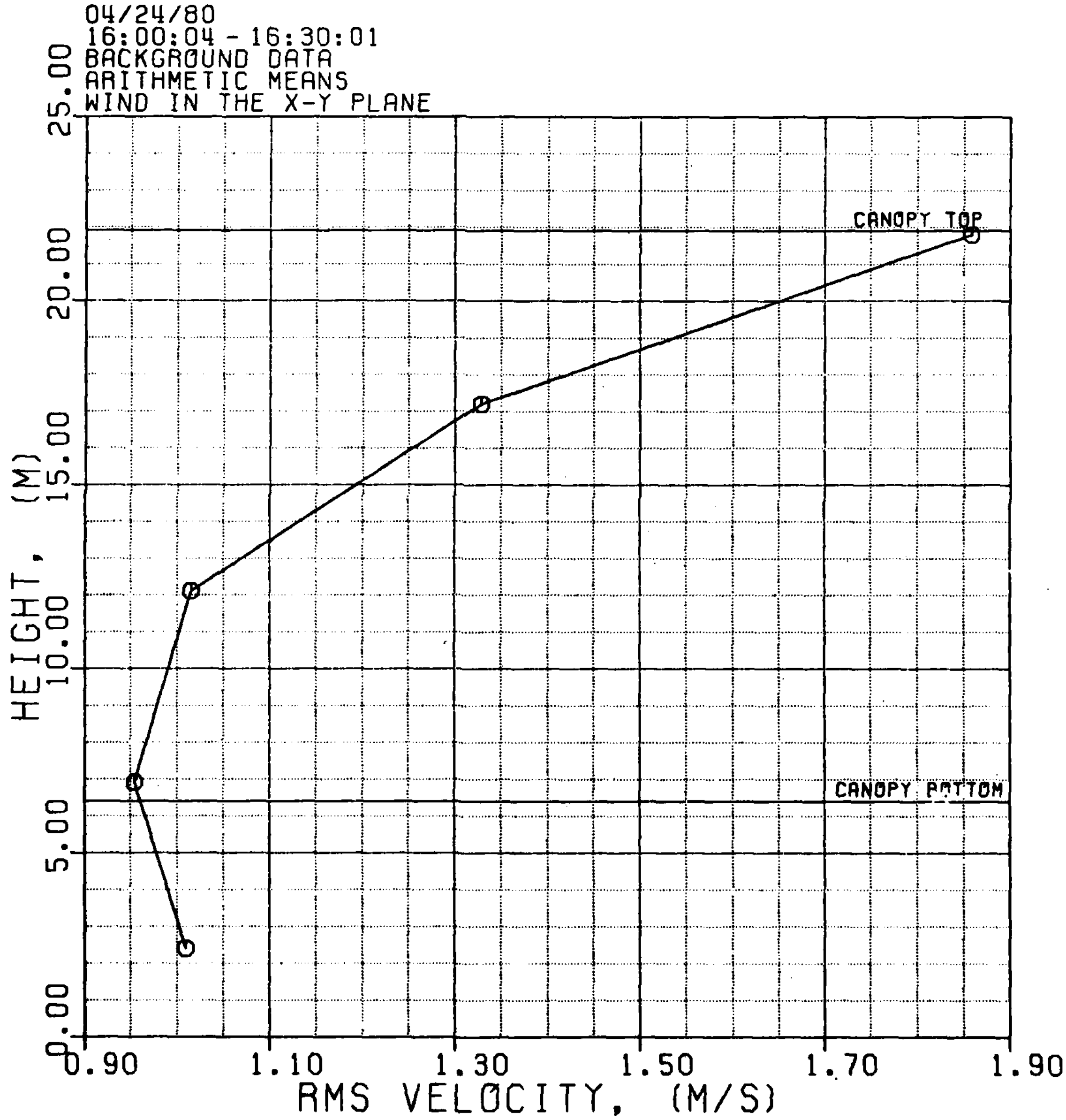


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
0.90
1.30
1.70
2.10
2.50
2.90
MEAN VELOCITY, (M/S)



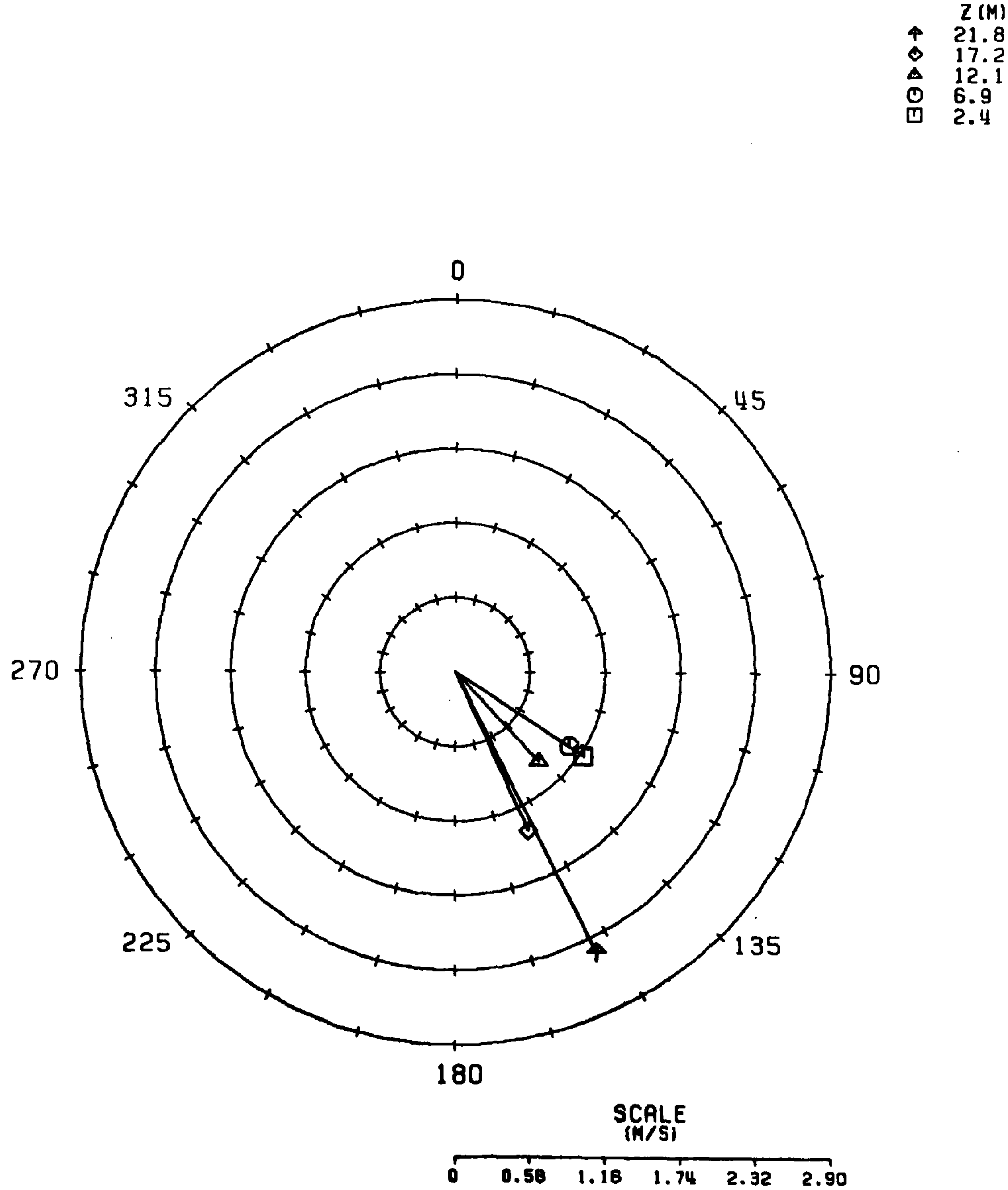
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
0.30
0.50
0.70
0.90
1.10
1.30
NORMALIZED


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
123.30
129.70
136.10
142.50
148.90
155.30
WIND DIRECTION, (DEG)

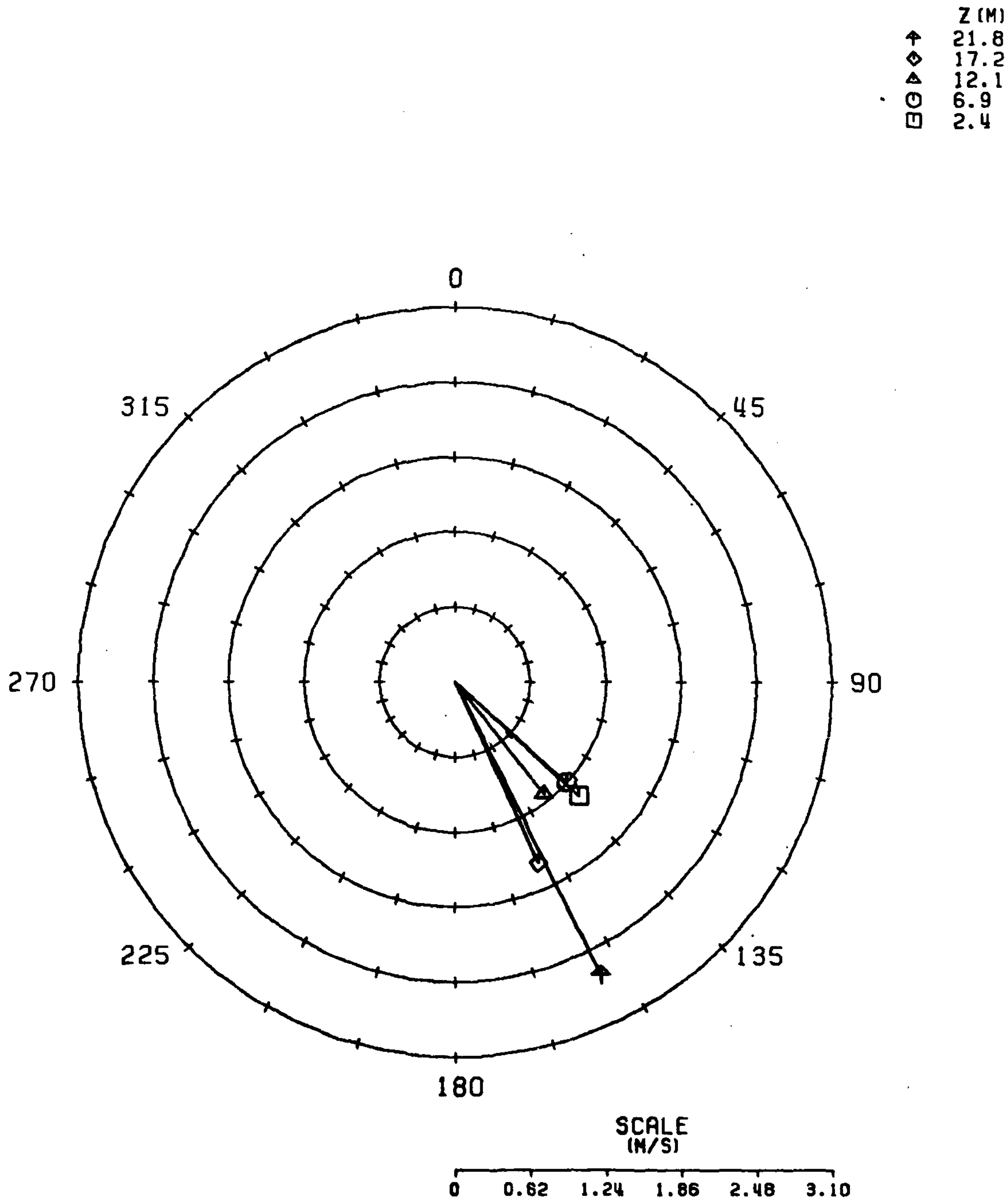


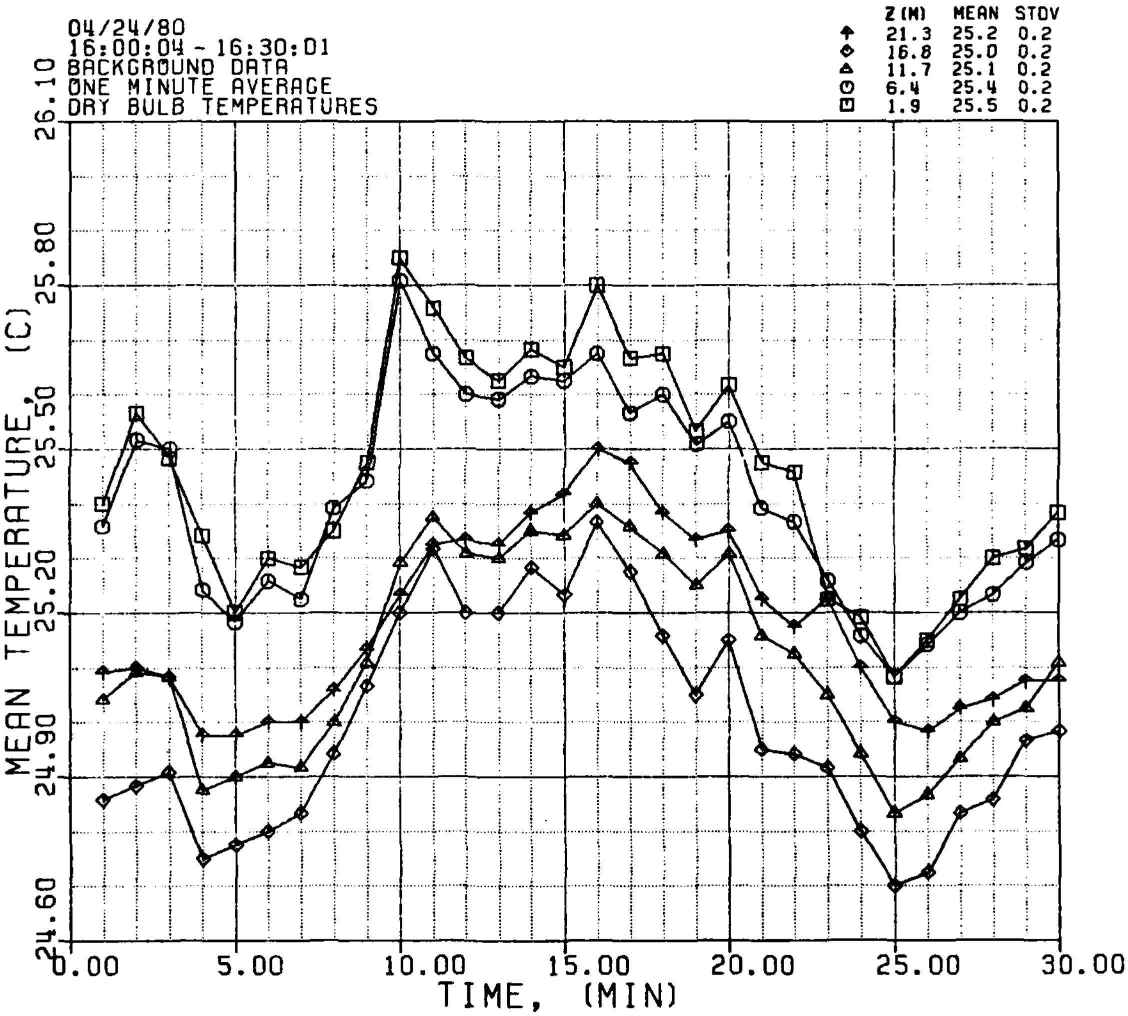
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
WIND IN THE X-Y PLANE
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
0.90
1.10
1.30
1.50
1.70
1.90
RMS VELOCITY, (M/S)

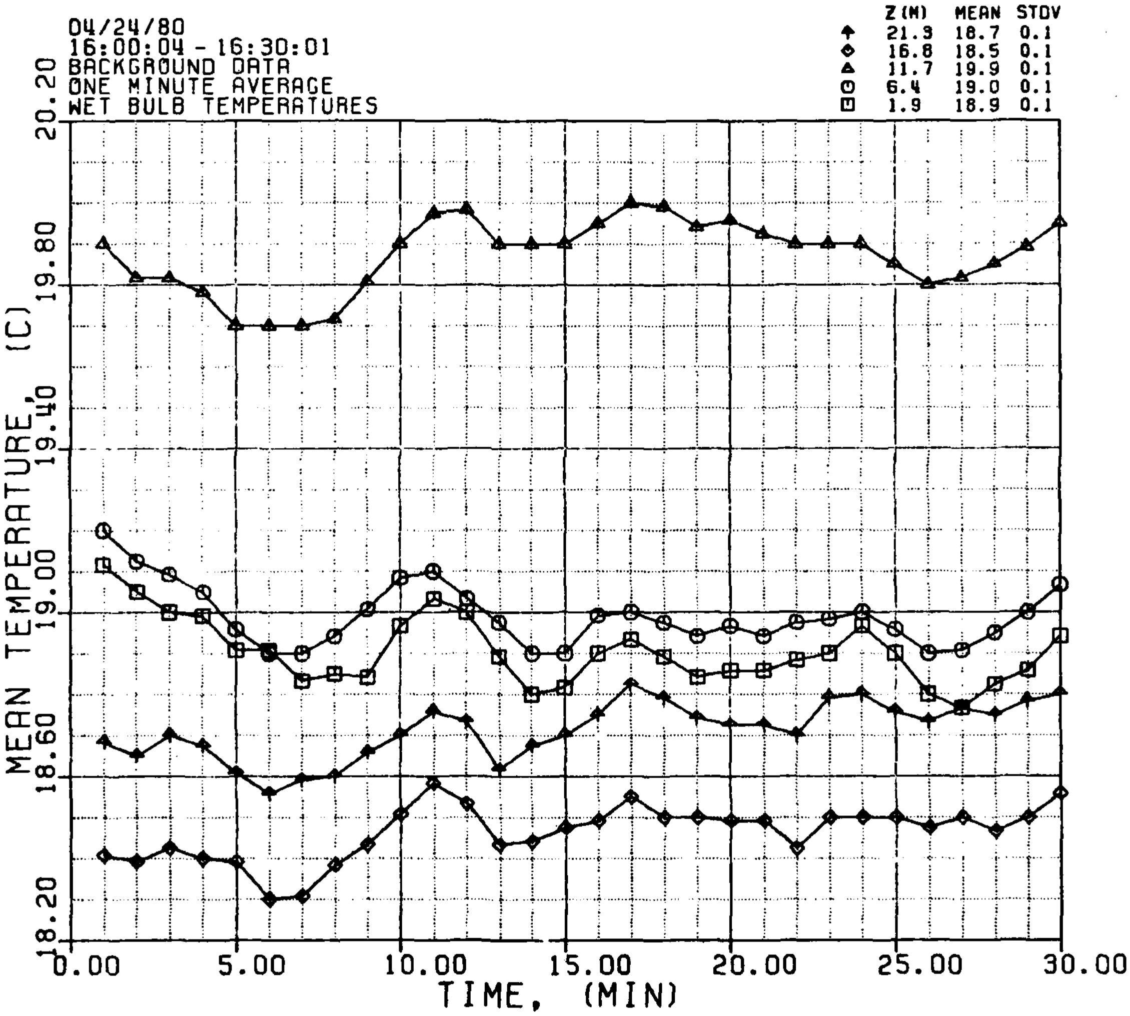
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
HORIZONTAL MEAN WIND
ARITHMETIC MEAN



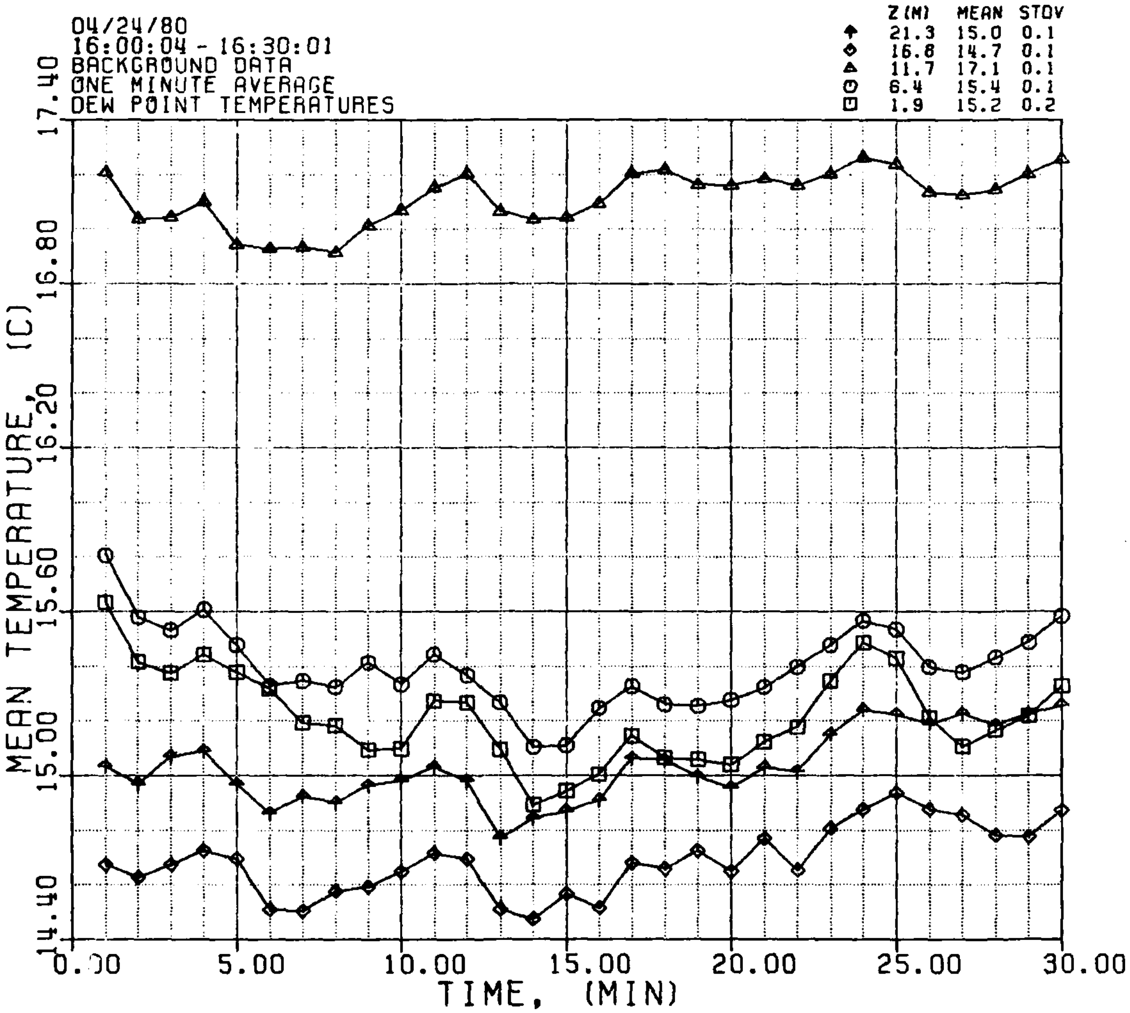
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
HØRIZØNTAL MEAN WIND
MEAN OF INSTANTANEOUS WIND VECTORS



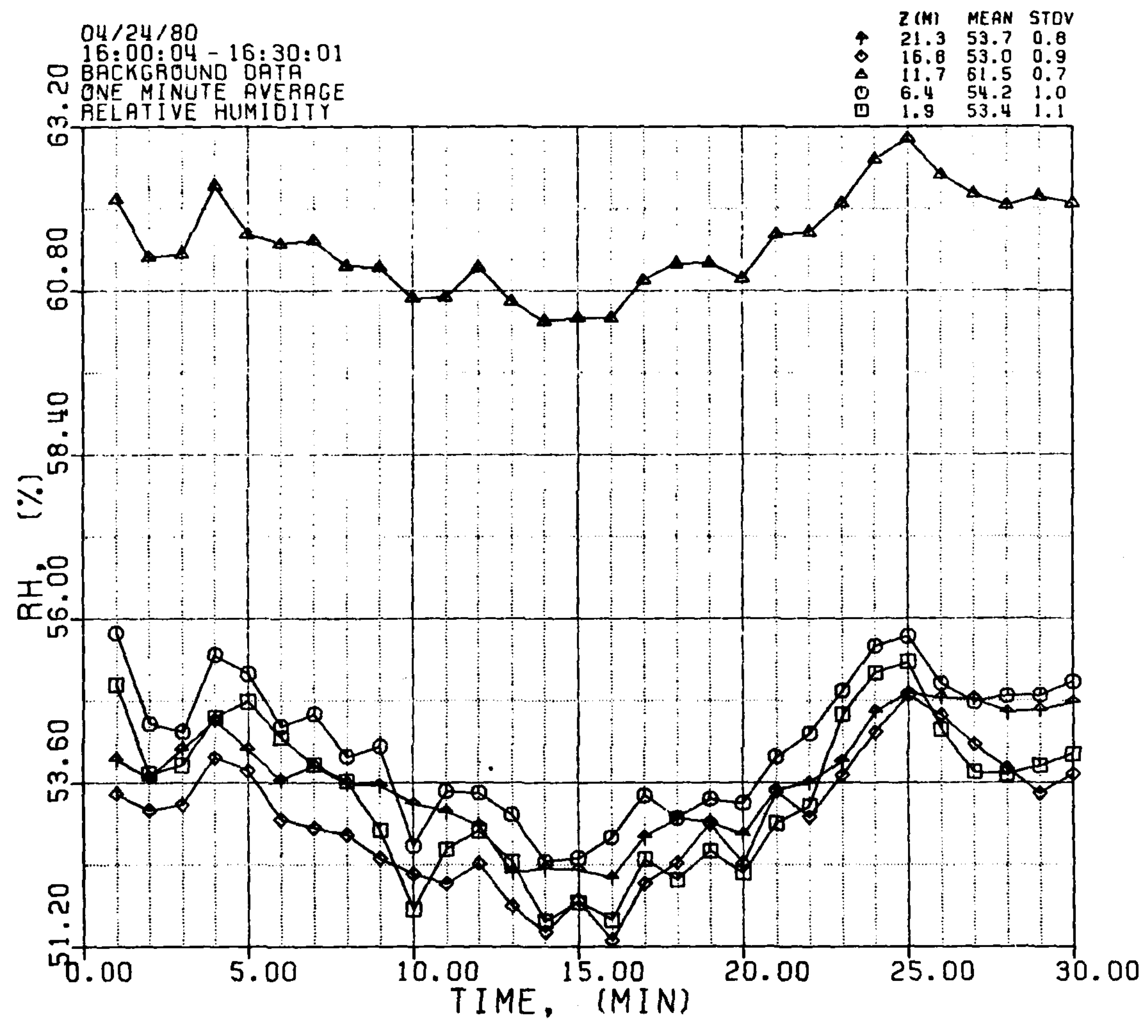

04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
DRY BULB TEMPERATURES
Z (M) MEAN STDV
21.3 25.2 0.2
16.8 25.0 0.2
11.7 25.1 0.2
6.4 25.4 0.2
1.9 25.5 0.2
MEAN TEMPERATURE, (C)
24.60
24.90
25.20
25.50
25.80
26.10
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)



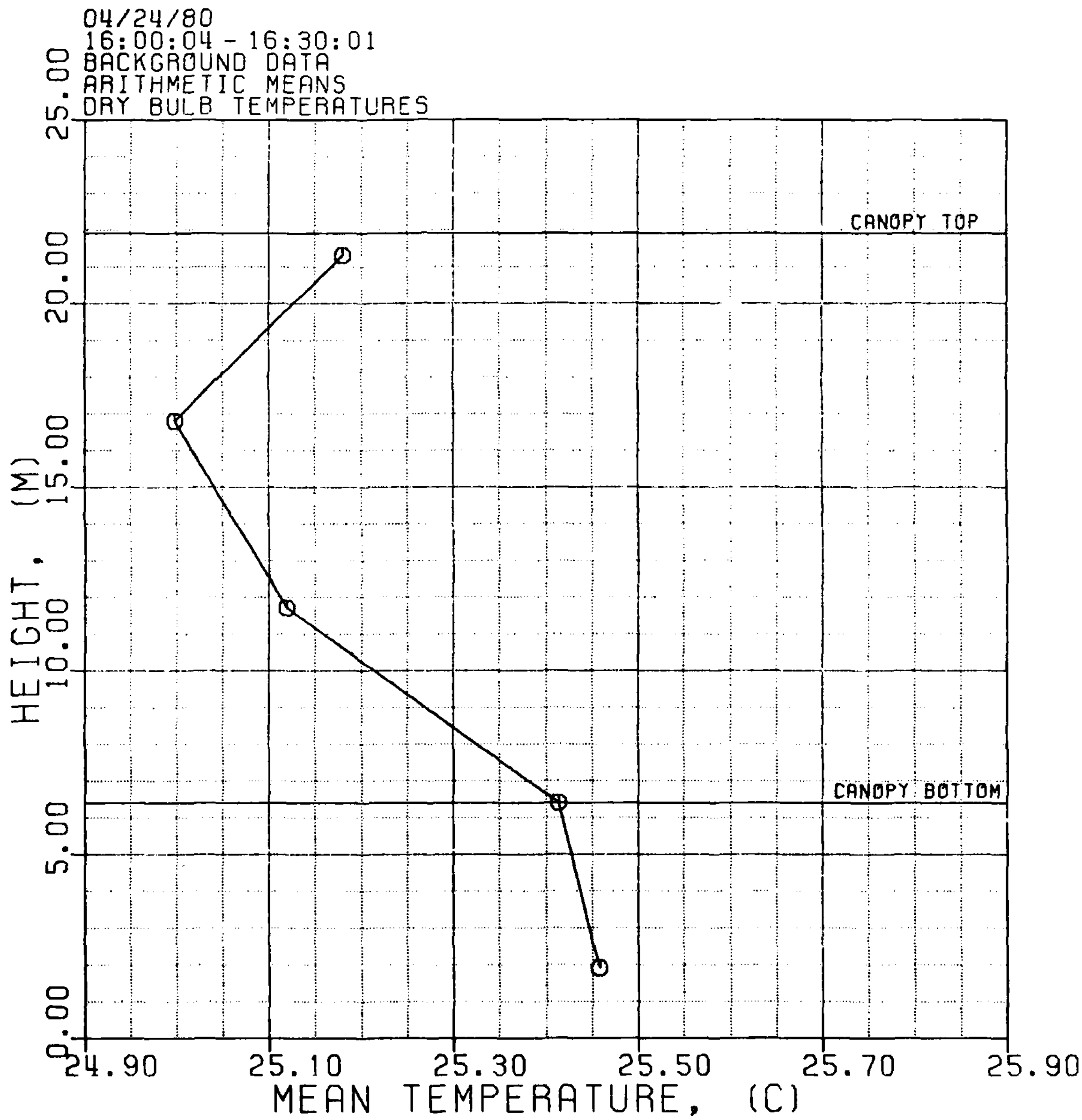
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
WET BULB TEMPERATURES
Z (M) MEAN STDV
21.9 18.7 0.1
16.8 18.5 0.1
11.7 19.9 0.1
6.4 19.0 0.1
1.9 18.9 0.1
MEAN TEMPERATURE, (C)
20.20
19.80
19.40
19.00
18.60
18.20
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

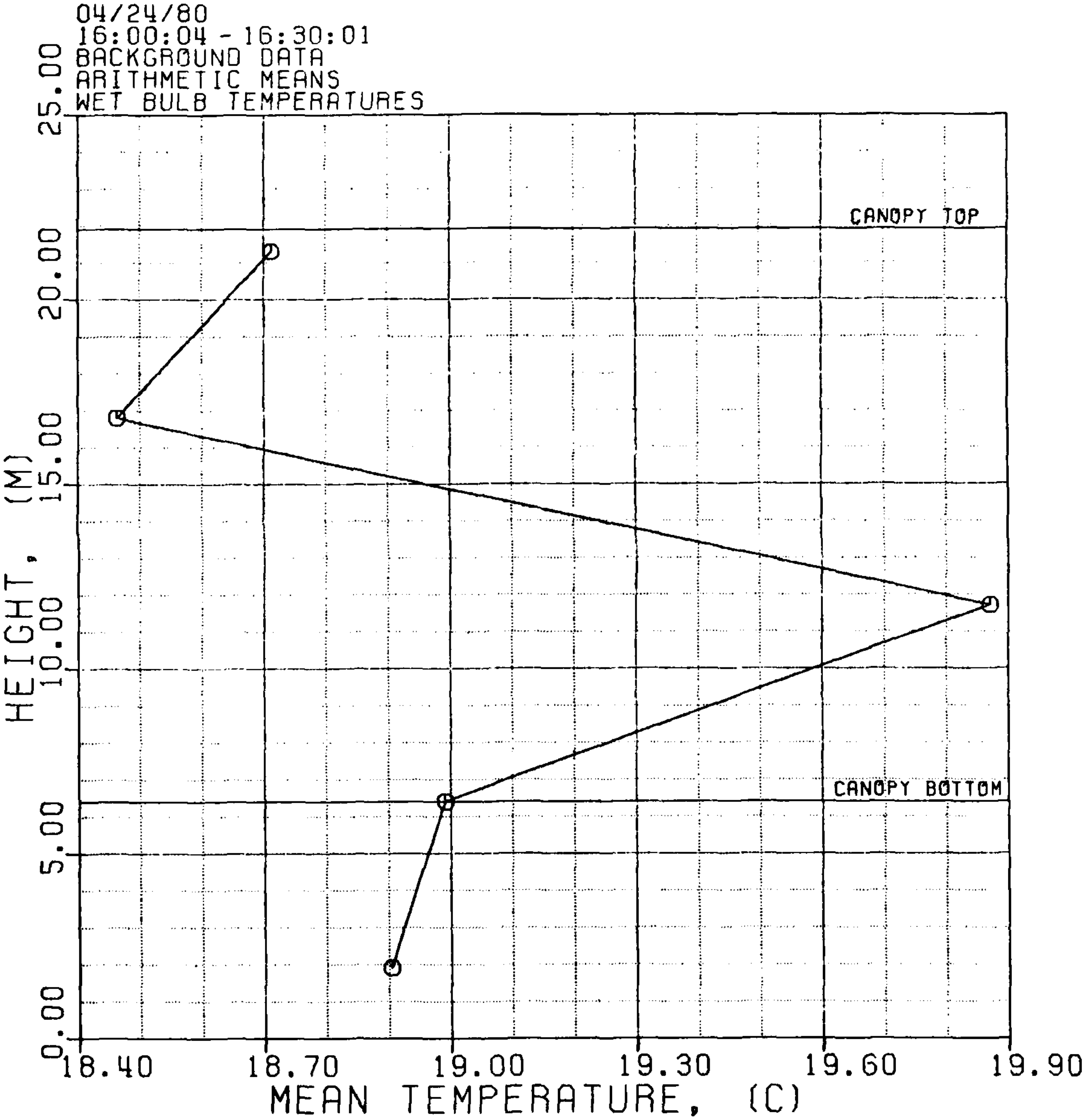


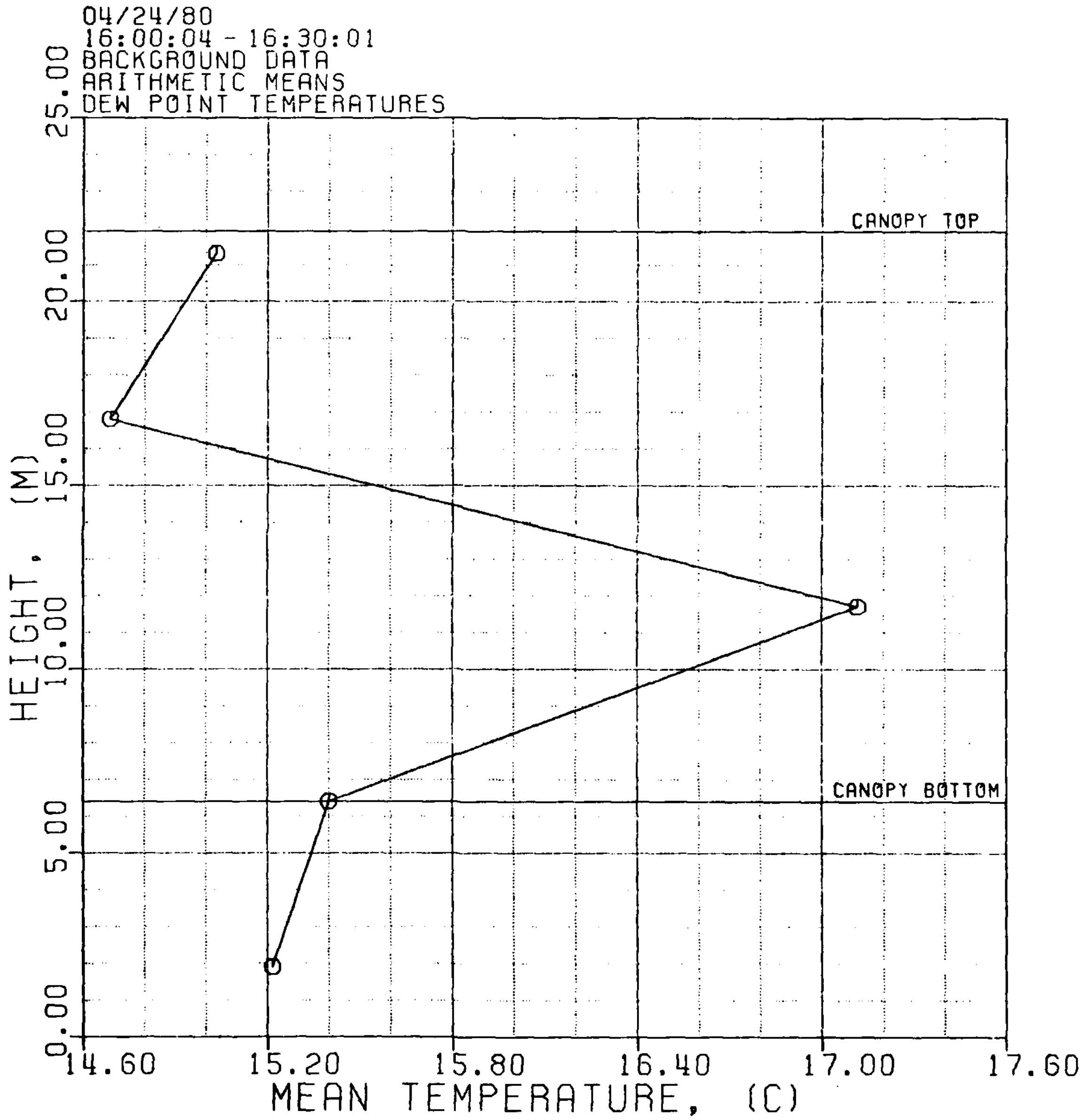
04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
DEW POINT TEMPERATURES
Z (M) MEAN STDV
21.3 15.0 0.1
16.8 14.7 0.1
11.7 17.1 0.1
6.4 15.4 0.1
1.9 15.2 0.2
MEAN TEMPERATURE, (C)
14.40
15.00
15.60
16.20
16.80
17.40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

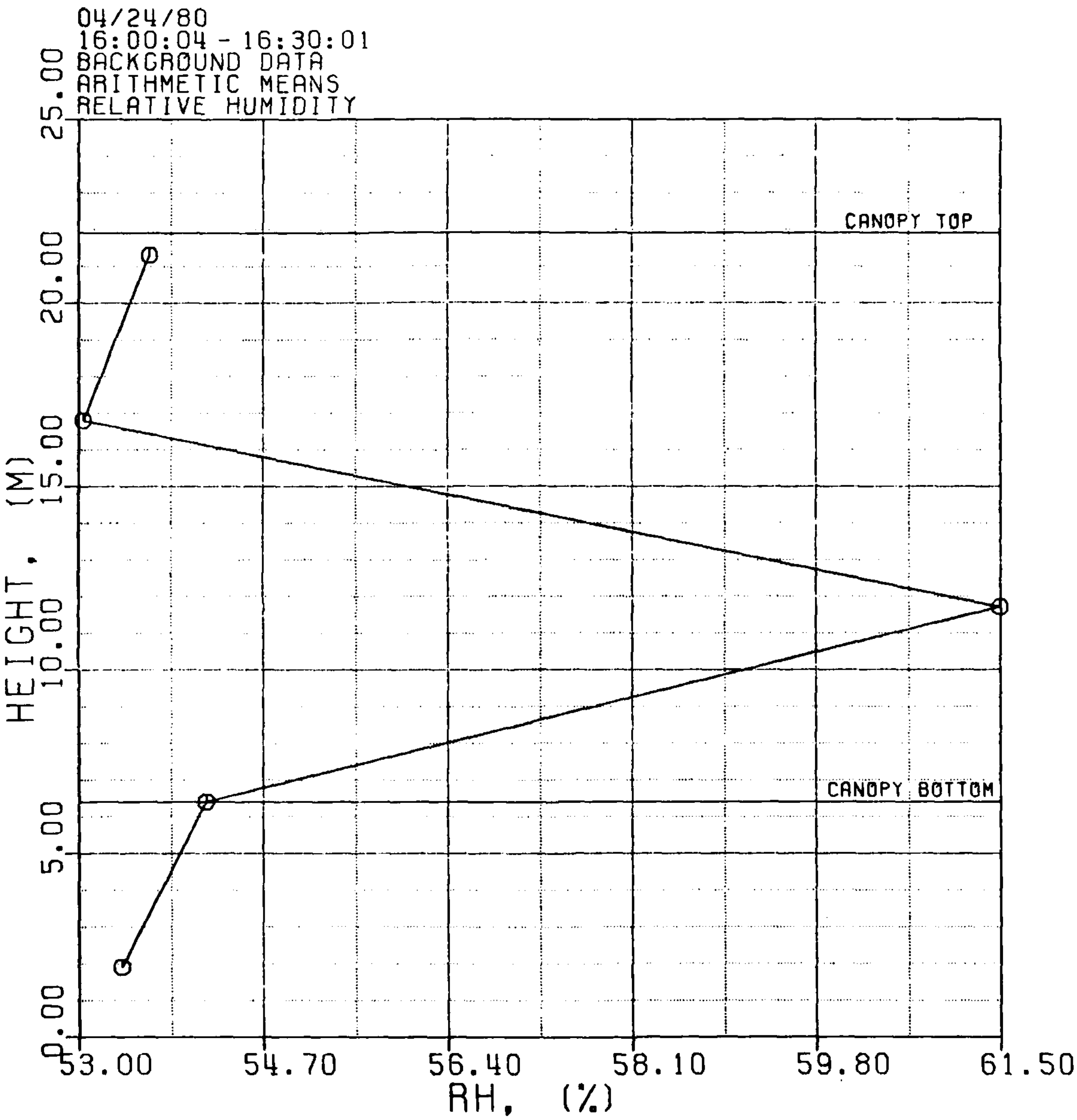


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
RELATIVE HUMIDITY
Z (M) MEAN STDV
21.3 53.7 0.8
16.8 53.0 0.9
11.7 61.5 0.7
6.4 54.2 1.0
1.9 53.4 1.1
RH, (%)
51.20
53.60
56.00
58.40
60.80
63.20
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)

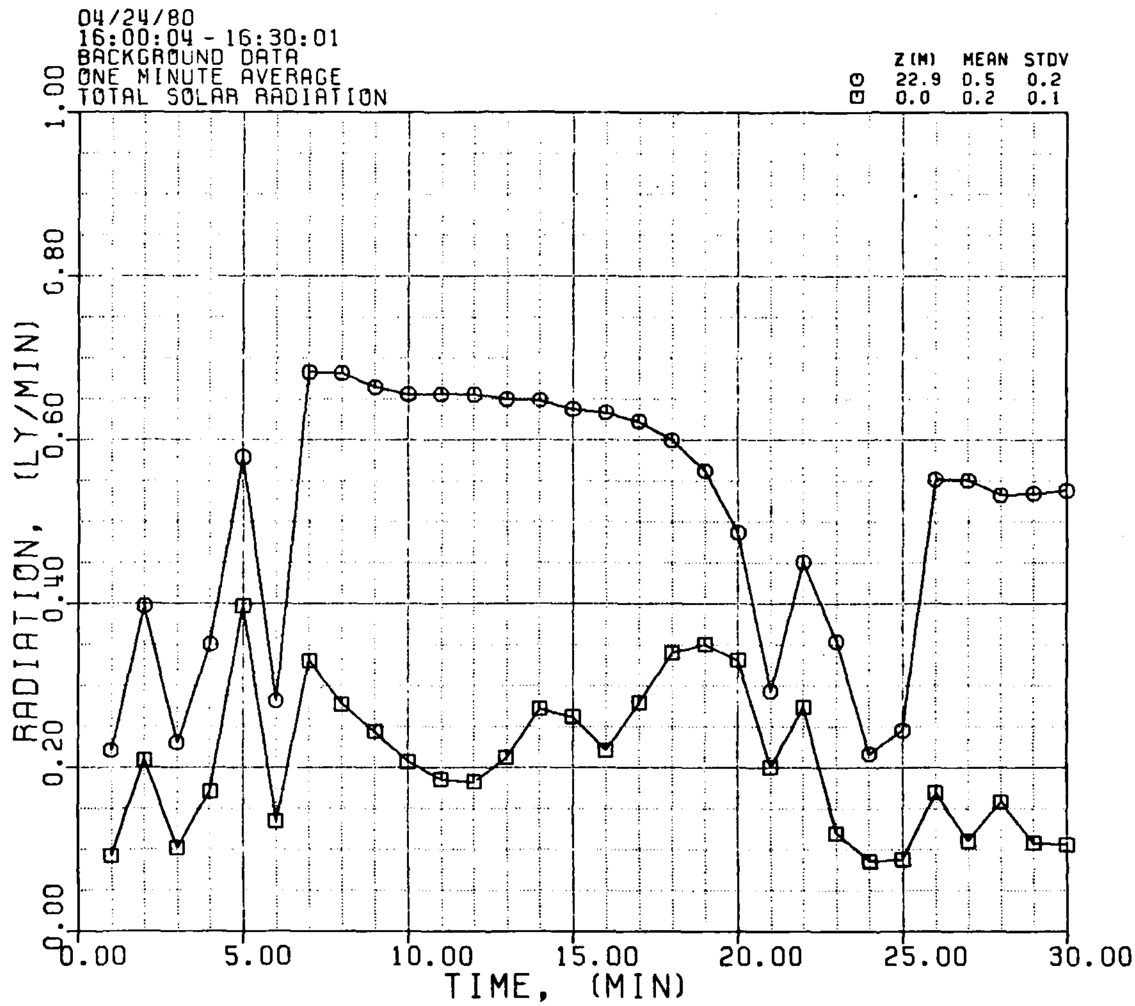

04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
DRY BULB TEMPERATURES
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
24.90
25.10
25.30
25.50
25.70
25.90
MEAN TEMPERATURE, (C)


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
WET BULB TEMPERATURES
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
18.40
18.70
19.00
19.30
19.60
19.90
MEAN TEMPERATURE, (C)


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
DEW POINT TEMPERATURES
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
14.60
15.20
15.80
16.40
17.00
17.60
MEAN TEMPERATURE, (C)



04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ARITHMETIC MEANS
RELATIVE HUMIDITY
CANOPY TOP
CANOPY BOTTOM
HEIGHT, (M)
0.00
5.00
10.00
15.00
20.00
25.00
53.00
54.70
56.40
58.10
59.80
61.50
RH, (%)


04/24/80
16:00:04 - 16:30:01
BACKGROUND DATA
ONE MINUTE AVERAGE
TOTAL SOLAR RADIATION
Z (M) MEAN STDV
22.9 0.5 0.2
0.0 0.2 0.1
RADIATION, (LY/MIN)
0.00
0.20
0.40
0.60
0.80
1.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TIME, (MIN)